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Preserving Arctic Archaeology in the 21st Century: Threats of Climate Change

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Archaeological sites around the world are facing many challenges. These challenges include urban expansion, resource exploitation, tourism, governmental infrastructure programs such as road development and one of the most recently recognized challenges is climate change. The archaeological record of the Arctic tundra is particularly sensitive to fluctuations in the climate, with its fragile ecosystems and ground underlain by permafrost. The impact of increasing global temperatures is a major public issue of the 21st Century, and the ramifications on archaeological sites are significant. The impacts felt over the next century are predicted to range from a sea level rise of almost a metre to a 6.4˚C rise in temperature (IPCC, 2007:13). Arctic archaeological sites often invoke a feeling of being in stasis, simply waiting for the next researcher to come along and discover them anew. In fact, the continued existence of these sites is taken for granted, and many are in fact under siege from environmental factors. While the Arctic may face some of the greatest environmental challenges to its archaeological record, it also has some of the greatest potential of *in situ* preservation in the world. The slow growth of infrastructure in many parts of the Arctic along with a very low population density has meant that threats from development are not as significant or pressing as in other locales both in Canada and throughout the world. This means that the potential to preserve the archaeological record for future generations and future technologies is substantial if the surrounding environment can be stabilized. This paper summarizes the effects of a warming climate upon archaeological sites and uses the Arctic as a focal point, as it is the northern regions that are currently recognized as the most environmentally vulnerable. The Sannirut site on Bylot Island, Nunavut presents an excellent case study on the importance of preservation policies as well as the practicalities on how it can be done with current technologies.

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Table of Contents

List of Figures

Chapter 1
Introduction

This paper will explore whether global warming is currently having an effect upon archaeological sites, particularly in the Canadian Arctic, and the nature of likely future effects of global warming on the archaeological record. It will also evaluate whether *in situ* preservation of archaeological sites in the Canadian Arctic is both a feasible and desirable heritage management strategy for governmental policy makers, archaeologists and environmental engineers in the face of potential harmful effects from global warming.

Archaeological heritage management of in situ archaeological sites in Canada and elsewhere is facing many challenges. These challenges include agricultural development, urban expansion, suburban development, tourism, governmental infrastructure programs such as road development, but one of the most recently recognized challenges is global climate change. The impact of increasing global temperatures is a major public issue of the 21st century, and the ramifications on archaeological sites are significant. The archaeological record of the Canadian Arctic tundra is particularly sensitive to fluctuations in the climate, with its fragile ecosystems and soils saturated by permafrost.

While the Arctic may face some of the greatest environmental challenges to its archaeological record, it also has some of the greatest potential of *in situ* preservation in the world. The slow growth of infrastructure in the Arctic along with a long history of very low population density has meant that threats from development have not been as significant as in other locales both in Canada and throughout the world.

This means that the potential to preserve the archaeological record *in situ* for future generations and future technologies, if the surrounding environment can be stabilized, may be greater than in other parts of the world.

Research on archaeological sites in the Arctic is an area of pressing concern due to the level of destruction possible caused by the increase of temperature thawing the sensitive permafrost that currently preserves artefacts and stratigraphy, as well as rising sea levels and erosion. Permafrost is a layer of soil that stays frozen year round. There is also an active layer of permafrost that is only frozen part of the year and it is the active layer that experiences regular freeze-thaw cycles. Permafrost effectively preserves perishable archaeological materials that in most other parts of the world have disappeared from the archaeological record. For example, at the Sannirut site (formerly known as Button Point), on Bylot Island, 1000-year-old, life-sized wooden masks from the now extinct Dorset culture were excavated (Park, 2008). Preservation of the masks was only possible because of their encasement in permafrost. The Sannirut site will be used in this thesis as a case study for the consequences of losing this protective layer of permafrost. This site is an excellent test case as there are data on the condition of the site dating back to the 1960s from site reports and published works.

There are two pressing points to consider in the preservation of Sannirut. The first deals with the practicalities – what is threatening the site, can it even be preserved, and how? The second issue is context – how to ensure what needs to get done to preserve the site actually happens, such as where preservation fits into current archaeological legislation and how to pay for it. There has been occupation of Sannirut for the majority of the last 4,300 years, creating a rich archaeological record of modern Inuit predecessors that deserves consideration into its future.

Remarkable preservation is being lost as the permafrost thaws and sea levels rise. Artifacts are being subject to exposure and erosion at an ever increasing rate. Along with this exposure, the context of the artifacts themselves (where the artifacts are buried in relation to other artifacts), is being lost as well. It is crucial that methods of preservation be tested and policies created to address these increasingly pressing issues.

1.1 Archaeological heritage as a public concern

The topic of archaeological heritage as affected by climate change needs to be a public issue because archaeology provides a tangible link to our human identity and the various societies of today have decided to place preservation of that physical heritage as a matter of value. The changing state of our climate is one of the largest issues moving human civilization today with many profound repercussions affecting a wide range of human activities. Although its effects upon the archaeological record are probably among the last that most people would think about, those effects will have profound consequences for the continued existence of many of the world's archaeological sites. However, if the current and potential issues are addressed immediately, then the likelihood of preserving the world's heritage will be drastically improved. The fact that global warming will indeed have an effect upon archaeology has been realized by some outside of the archaeological field. In fact leading professionals in global warming initiatives have expressed specific concerns. For example, Under-Secretary-General of the United Nations, Achim Steiner stated at the 12th Conference of the Parties to the UN Framework Convention on Climate Change in 2006 that:

> "*We must… use our intelligence and scientific know-how to assist managers of culturally important sites like buildings and archaeological finds. Losses here as a result of climate change may impact on the livelihoods of local people…"* (Jerome, 2007:192)

To adapt to a changing climate, communities, heritage management professionals, politicians and scientists will need to take a multi-disciplinary approach to safeguard the non-renewable cultural resources that provide links to the past as well intellectual and economic stimulation to benefit both local and broad populations.

I am in agreement with May Cassar (2005:2) in that nothing is possible to preserve 'forever' or that every site is possible to preserve immediately. A relative value must be placed on archaeological sites in order to prioritize resource expenditures. Taking measures to stabilize threats to sensitive environments however, can only provide a much needed cushion to maximize the probability of preserving the archaeological sites deemed highest in potential returns. By choosing to preserve sites *in situ*, time becomes an ally instead of an enemy. Time can be taken to prioritize sites, to develop strategies of threat mitigation, salvage excavation, or even make the decision to let the environment do what it will.

In 1999, there was a public survey done in British Columbia, Canada to discover public opinion on archaeology, cultural resource management and site preservation. A large majority–85% of public opinion supported the preservation and protection of archaeological sites. The problem that the survey identified, however was that 73% of those surveyed had absolutely no idea of the legislation currently in place to protect archaeological sites now and in the future (Levy, 2007:173). Surveys such as this demonstrate the Canadian societal value placed upon archaeological heritage. Social responsibility is one of the prime motivators to establish preservation policies to cope with changes wrought by global warming.

> *"Heritage sites have the power to provoke public introspection, reawakening cultural memories of crises met, and by reminding us of our varied pasts, suggest the possibility of alternate futures."* (Petzet, 2007:195)

It is important to consider the responsibility that government has as caretaker of a nation's heritage. Public accountability involves preserving, opening up access to information and to archaeological heritage for descendent communities as well as the general public. The above quote in a publication of ICOMOS (International Council of Monuments and Sites), is an indication of the rewards that adequate preservation and management strategies can have. At this time, however, only a few places, such as Greece (to be discussed in Chapter 3), have any sort of heritage legislation that takes into account environmental degradation due to global warming. Canada is not one among these few.

In the second chapter of this thesis the basic scientific aspects of global warming and the effects it can and is having on the archaeological record are discussed. Chapter three continues this with actual case studies from around the world on the regionally different effects a warming climate is currently and predicted to have on specific archaeological heritage. Chapters four and five focus on the Sannirut site of Bylot Island, Nunavut. These two chapters will consist of the practicalities, such as how the site is deteriorating and how the permafrost can be stabilized, as well as the context of preserving Sannirut and other Arctic archaeological sites, such as existing heritage legislation and how and who may pay for it. I will also explore in Chapter five, major international initiatives and models that may be possible for Canada to emulate in the creation of heritage management plans to preserve archaeological sites threatened by climate change.

Chapter 2
Climate Change

2.1 What is Global Warming and how is it happening?

> " 'Climate change' means a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods."

This is the definition as of 2010 of climate change put forth in Article 1 of the United Nations Framework Convention on Climate Change (http://unfccc.int/essential_background/convention/background/items/2536.php).

In order to understand the current and potential effects of Global Climate Change on the archaeological record, it is first necessary to understand the nature of the process of climate change. The earth's climate is influenced by the greenhouse effect which is a result of gases in the atmosphere, such as methane, that contribute to the retention of heat and the amount of radiation reaching the earth from the sun or reflecting from and back to the surface of the planet. It is also influenced by thermohaline circulation which transports heat in the oceans from the equator to the poles. The oceans heat up at the equator and then circulate to either pole causing the melting of sea ice resulting in less radiation reflecting back to the atmosphere, which in turn will feedback in an increase in earth's temperature (Gascard, 2009:28). The earth's capacity to retain heat is necessary to the survival of all life forms, but retaining too much leads to global warming. Climate change is manifesting itself in the 21st century as a global warming trend, steadily increasing its average mean annual temperature (Claussen, 2001:16). Global surface temperatures have been recorded since 1850, and the data show a steadily rising slope (Adams, 2007:194).

The earth has gone through fluctuations in temperature throughout its history. Palaeoclimate data models are created through celestial mechanics, measurements of solar activity, recorded volcanic activity, tracing gases trapped in glaciers and ice caps and through dendrochronology. The mid-Pliocene, approximately three million years ago, is the nearest sustained period of time in which global temperatures approximated current times. This period may have even been a couple of degrees warmer (IPCC, 2007:440).

Sea levels during this time were 15 to 25 metres higher than today with minimal global ice coverage, giving a good indication that current ice coverage will also diminish substantially or disappear entirely (IPCC, 2007:442). For the last three million years, there have been increased temperatures experienced during interglacial periods such as the Mesozic Era, 230 to 65 mya, but none on par with our current situation. Ice core samples indicate that one of the reasons for this is the 25% increase in carbon dioxide and the 120% increase in methane in the atmosphere beginning in the industrial era (IPCC, 2007:447). Glaciers around the world have also indicated periodic and sometimes significant retreat or disappearance but never before on a global scale as experienced in the 21st century (IPCC, 2007:461).

The differences we are currently facing versus past changes, include the rapidness and degree of the increase which is faster than any seen in recorded times. These trends show no signs of ceasing, as well as the cause of those changes which a majority of people believe is anthropogenic (Adams, 2007:194). The last great period of warming that had comparable levels of carbon dioxide was millions of years ago and those levels accumulated over a period of 5000 years. We have managed to reach these same levels within the last 50 years (IPCC, 2007:465).

The current warming conditions are mainly caused by an accumulation of greenhouse gases in the atmosphere that has been increasing since the industrial era of the 1800s, in some cases more than doubling the concentration amounts (Wigley, 2001:7). There is an innate greenhouse effect that moderates the planet's regional climates. It is caused by naturally occurring atmospheric gases that are balanced by naturally occurring processes called 'sinks' that absorb these gases. Anthropogenic (human-caused) climate change exacerbates the greenhouse effect by introducing more of these gases as well as synthetic ones to the atmosphere, tipping the balance until natural sinks can no longer compensate (Wigley, 2001:8). The most common of these gases are methane, carbon dioxide and nitrous oxide which are released through the burning of fossil fuels, thawing permafrost and deforestation. The greater the accumulation of gases, the higher the heat retention of the atmosphere resulting in a general average increase in surface temperatures (Adams, 2007:194).

The evidence for an anthropogenic warming climate is found in a variety of places. Ice cores taken from ice caps and glaciers, such as from Antarctica, allow for the composition of air trapped within to be measured. The ice cores can allow for testing going back more than 740kyr, making them excellent for comparison to modern samples (IPCC, 2007:440). Meteorological data from ships and land station in some regions go back more than 200 years, allowing for much more detailed regional data, although this evidence is heavily weighted to the northern hemisphere (Wigley, 2001:9). Dendroclimatic data that can span more than 600 years. Dendrochronology or tree ring dating is a very effective dating technique which can be applied to climatic events. Dendroclimatic data measures annual temperature based of the width of tree rings in a region, wider and narrower depending on that years climate. Trees are extremely sensitive to fluctuations in the environment and have the added advantage of being able to track changes on a regional and not just global scale (Briffa, 2004:11). The oceans are also a source of data from oxygen isotopes, pollen accumulation, to carbonized life forms such as chironomids that are highly sensitive to temperature fluctuations. Ocean floor sediments can provide data spanning the length of the Holocene (Lang, 2010:1528).

To predict climate change trends, scientists take historical data from these proxy sources, and develop mathematical models representing climate change. These scenarios can differ depending on the amount of data entered and the level of detail required (IPCC, 2007:12). The Intergovernmental Panel on Climate Change (IPCC) models predict that even if emissions stabilize or are reduced to year 2000 levels, there will still be an increase of approximately 0.1˚Celsius in the average global temperature per 10 year period along with a continued rise in sea level due to thermal expansion and melting ice caps. These increases are predicted to last for centuries even under stabilized model numbers, as the reversal of gases in the atmosphere and climatic feedback loops involves massive time scales (IPCC, 2007: 16-17). Predictions based on IPCC models since 1990 have shown a fair degree of accuracy, with the actual 0.2˚Celsius increase in global temperatures falling within predicted ranges. The latest models predict an increase in sea acidification, active layer permafrost thaw depths, heat waves, tropical cyclones and temperatures, with a decrease in sea ice and snow covered areas. The greatest increases in temperature and precipitation are predicted to occur in high northern latitudes (IPCC, 2007:14-15).

2.2 What is happening

The exact consequences of a warming climate vary with locality. Most areas will see a warming trend, although a few areas are beginning to see a cooling trend. This is most visible in Arctic regions where local climate varies greatly from one region to the next. The general global predictions are for a temperature rise between 1.4 and 6.4 ˚C within this century (IPCC, 2007:13). At the time of the last IPCC report in 2007, the previous 11 out of 12 years had seen the highest recorded global temperatures (IPCC, 2007). The rising heat will see a corresponding increase in sea levels of nearly one metre which can be expected to decimate low-lying areas (Adams, 2007:194). Sea levels will increase through thermal expansion (which also increases air moisture levels) and the melting of glaciers and ice caps. Combining higher temperatures with increased humidity creates an increase in the frequency and ferocity of extreme weather events in many areas. Other areas such as the subtropics will experience, and in some cases already are experiencing, drier conditions as moisture is drawn away from equatorial regions, exemplified in droughts and wildfires (Adams, 2007:194-195).

2.3 Arctic specifics

The Arctic is often acknowledged to be the first indicator of broader global trends with its sensitive environment. The visible effects of global warming are presently most prominent in Arctic zones which have fragile eco-zones and minimal human developments to obscure the landscape. One of the most visible signs is the decrease in sea ice extent, with 2007 seeing a record low (Goodison, 2009). Temperature increases in the Arctic mean more extreme seasonal cycles of active layer permafrost freeze-thaw, and soil moisture levels creating a great deal of ground disturbance (Goodison, 2009).

In terms of affecting climate variability the cryosphere is second only to the oceans. The cryosphere consists of ice, glaciers, permafrost, ice shelves, etc. Permafrost is the largest component of the cryosphere. Permafrost refers to ground containing a high ice content that is permanently or semi-permanently frozen for all or part of the year; 51% of the Northern Hemisphere falls into at least a seasonal permafrost region (IPCC, 2007:341-342). Permafrost is extremely vulnerable to the rising temperatures of global warming, and can create a feed-back loop accelerating the process. Large amounts of the greenhouse gases methane and carbon dioxide are contained in the permafrost. When the ground thaws, these gases are released, which in turn increases global temperatures looping back towards an even larger amount of thawing (IPCC, 2007:110). The warming potential of methane is approximately 20 times that of carbon dioxide. The magnitude of the problem of permafrost lost is illustrated by the fact that the entire human output of methane per year is approximately 5.5 gigatons, whereas the permafrost in the Siberia alone contains approximately 500 gigatons (Shoumatoff, 2009:41).

Sea Ice is another key component of the cryosphere. As of 2009, the September Arctic sea ice extent was 1,680,902 square kilometers below the 1979-2000 average, according to CU-Boulder's National Snow and Ice Data Center (http://nsidc.org/), and it is declining at a rate of 14 percent per decade (Heritage at Risk, 2007:203). At this pace it is possible that the Arctic will experience ice-free summers within ten to twenty years. The reflective nature of sea ice is crucial to how much radiation is absorbed into the ocean–the less ice, the more radiation is absorbed leading to warmer temperatures and even less ice. Loss of glacier ice has a similar effect as well, leading to a rise in sea level if the loss is extensive enough, such as the Greenland glacier which is receding and becoming thinner every year (Goodison, 2009:37).

2.4 What effects can climate change have on the archaeological record?

There are many examples of the threats of an increasingly erratic climate on cultural heritage sites around the world. The cultural losses of archaeological heritage, if climate change is left out of management plans, are appalling. World heritage sites such as the Tower of London could easily be destroyed by flooding. The financial losses for many nations would be significant in terms of tourist dollars from cultural tourism being cut off, as well as expenses incurred by restoration (Egloff, 2007:200). Spontaneous weather events aside, the rapidly warming temperatures are also threatening to bring a rise in sea levels and water tables to a conservative half metre above present levels within this century (IPCC, 2007:7). Climate change can also have other direct effects on the archaeological record such as soil humidity and composition that can radically alter states of preservation of artifacts. There are also indirect effects such as the migrations of people or industries that have been displaced by environmental conditions that will be described below. The migration of large displaced sectors to undeveloped areas will have ramifications upon the archaeological record through development of previously undisturbed land (Adams, 2007:195).

2.4.1 Sea level rise and coastal erosion

Sea levels rise through a combination of the melting of ice caps and glaciers and thermal expansion (warm water expands). Rising sea levels also correspond with rivers becoming backed up and flooding, creating problems further inland.

Annual temperatures are increasing in the Arctic at double the speed of the rest of the world. Permanent (or previously year-round) ice is facing an annual reduction of 14%. (Heritage at Risk, 2007:203). A 10 centimetre rise in sea level is partially the result of the reduction in sea ice and thermal expansion of the oceans over the last four decades (Blankholm, 2009:17).

The Intergovernmental Panel on Climate Change has predicted a rise in sea level by approximately 50 centimetres within the 21st century (Olynyk, 2007:212). This can be expected to have catastrophic effects on the coastal archaeological record. Coastal erosion can sweep entire buried and built archaeological sites into the sea. It can also damage and weaken soil beds so that sites can collapse in upon themselves. In northern regions erosion thaws the permafrost causing slumping and the decay of organic artifacts. In the last decades various coastal areas are already seeing dramatic losses. In some cases, such as Barrow, Alaska, up to 30 metres of land is being swept away through erosion annually (Barr, 2009: 146). Within the next millennium however if the polar ice sheets of Greenland and Antarctica experience a partial melting sea levels could rise up to six meters from their current levels, effectively devastating any low-lying archaeological sites around the globe (IPCC, 2007:15).

2.4.2 Sea acidification

As sea levels rise there is expected to be a corresponding increase in the acidification of the water (Blankholm, 2009:18). This is caused by an increase in the amount of vegetation and other organic materials that are absorbed into the water that degrade and alter the pH balance of the water towards acidity. The increase in acidification will cause the most impact on sites and artifacts that contain a high alkaline (or organic), content such as shell middens or bone artifacts. This is caused by the acidity of the water eating away at any organic matter. Eventually organic artifacts will dissolve completely in acidic conditions. The geographic range of this impact is global, affecting sites already submerged as well as ones that will be inundated in the future and sites simply located along coastal regions that will see wave action as well as a high water table (Blankholm, 2009:18).

2.4.3 Increased precipitation

With warming temperatures there is a strong likelihood of precipitation increasing by up to 40% in regions of higher latitudes. Higher rainfall increases the quantity and severity of floods along lakes and rivers which are areas most likely to be populated with archaeological sites (Blankholm 2007:18, IPCC, 2007:2).

Bio-deterioration, mold and decay are also expected to create difficult problems in regard to wooden artifacts or built heritage in areas that are becoming waterlogged and facing increased humidity and precipitation. The difficulties arise for artifacts that are currently preserved in dry soils or regions with low humidity. Artifacts in dry regions have never been exposed to mold or organisms that can cause decay, organisms that can thrive in moist environments. Arctic and Antarctic regions, whose cold dry climates previously favoured wooden preservation, are most at risk from these issues since they are experiencing the highest increases in precipitation (Greenwood, 2008:67).

2.4.4 Warming water and altered pH composition

The superb but fragile preservation offered to organic remains by bogs will undergo a detrimental chemical change caused by the warming temperatures of the water logged areas. Presently these areas have a very high acidic content and therefore preserve protein materials. The mud and sediments that bury archaeological sites serve to seal off artifacts from harmful organisms and the damaging effects of exposure to the elements. An increase in fresh water runoff infiltrating bog lands as well as an increase in temperature from surface warming alters the pH balance in the saturated soils and water from the original conditions in which the artifacts were preserved in. There is also the risk that protective sediments will be washed away exposing sites to the elements. Fragile human remains as well as organic material such as antler or fiber clothing will begin to degrade much more rapidly with exposure to foreign organisms and warmer water (Blankholm, 2009:19).

2.4.5 Bush/wild fires

Over the last two decades the frequency and intensity of wildfires has increased dramatically around the world, particularly around the Mediterranean, in Africa and in Australia. It is the drought combined with changes in soil humidity and an increase in lightning (all due to increased climatic temperatures), that are leading to the increase in large-scale fires. Fires have an obvious effect on built heritage where anything built of something other than stone is destroyed. Even stone buildings can be partially destroyed if they have wooden supports or contents. Artifacts in the ground can be damaged by fire as well. The heat can destroy organic remains such as wood or bone, with high enough heat, spalling or breaking of pottery and stone can also occur (Haecker, 2001). Buried archaeological sites are impacted heavily by heat damaged soils after the fire is gone. The soil is much more easily eroded away by wind or water causing exposure of the artifacts and disruption of the stratigraphy (placement of artifacts), in a site. Massive fires create another danger to important monuments, sites and buildings in the form of flooding. When protective vegetation is stripped and the soil is dry and damaged there is little protection from flooding of major rivers (Kolonia, 2007).

Arctic tundra fires are phenomena that is not well known, but the frequency of which is expected to rise dramatically within this century with warming Arctic temperatures and an increase in tundra vegetation. Tundra fires can be caused by the same means as anywhere else such as lightning or the spread of human fires. They can spread rapidly and with very little impediments in their way, causing a great deal of damage to fragile archaeological remains which are not covered, or very minimally buried as is the case of most archaeological sites in the Arctic. Tundra fires also cause thawing of the permafrost which in turn can release more carbon dioxide and methane to the atmosphere which leads to further warmth retention (Higuera, 2008).

2.4.6 Changes in water tables and moisture content

A rise in sea levels and rainfalls will result in a higher water table in some geographic locations. A high water table in turn can result in the water-logging of archaeological sites and artifacts and may increase or create problems of dampness in buildings and structures. Changes in the water table can make an archaeological site difficult to access or even cause it to be submerged completely. The water also increases the rate of decay in organic materials as well as destabilizing the stratigraphy in a site by causing compression or churning of the soil (Cassar, 2005:25).

Changes in drainage patterns may also occur with a change in the water table; areas that were previously clear of run-off may become in the direct path of it, causing archaeological sites in its path to become victims of erosion caused by rapidly moving water. There is also the additional risk of water tables changing chemistry due to an infusion of salt water which will lead to a difference in corrosion and degradation rates of features, artifacts and structures. This is a particular concern in ecologically fragile archaeological sites contained in areas such as fresh water bogs where salt would corrode the artifacts (Cassar, 2005:25).

In areas experiencing drying conditions where the water table is lowering, the effects on the buried archaeological record can be indirect. For example, as soils dry out they can experience heave, slumping or cracking which has extremely damaging effects on the reliability of the stratigraphy of the site. The same types of effects are experienced in areas that are exposed to increasingly extreme cycles of freeze-thaw which will be discussed below in relation to permafrost (Cassar, 2005:26).

2.4.7 Desertification

In some arid or semi-arid environments extreme heat and wind events are escalating the rate and severity of shifting sands and desertification leading to the burial or destruction of large scale buried and built archaeological sites (Huang, 2009:56). Sand moved by wind can cause destruction of buildings and features by abrasion and pitting. In areas experiencing desertification, entire dunes are gradually shifting with wind action and are capable of engulfing entire cities. Shifting dunes can also reveal long buried monuments, although this in turn does make the revealed sites vulnerable to sand abrasion (Qu, 2007:153). As global warming mounts, precipitation will continue to shift away from equatorial regions leaving vulnerable populations attempting to cope with survival rather than putting funding towards heritage preservation.

The hardest hit will be places such as Africa where almost 25% of the continent is currently facing desertification. It will be regions in these circumstances, with the lowest economic resources to combat desertification, that face the greatest cultural losses as these regions will not be able to spare the funds for relocation, protection or the restoration of sites already damaged (Adams, 2007:195).

2.4.8 Permafrost thaw

Permafrost is extremely sensitive to freeze-thaw cycles, causing large scale slumping and upheaval and turning of the soil, which in turn causes any buildings on top to destabilize and the stratigraphy of buried sites to be destroyed. Slumping and upheaval can also churn artifacts to the surface leaving them vulnerable to the elements, humans and animals that may inadvertently cause damage. Thawing permafrost also can lead to organic artifacts becoming waterlogged and decaying as opposed to the molecules being frozen and protected. Thawed permafrost is also extremely vulnerable to erosion from receding sea ice that leaves shorelines exposed to high waves caused by violent storms. Mass erosion can sweep entire archaeological sites, both built and buried, into the sea (Olynyk, 2007:211).

2.4.9 Insect and organism infestations

Increases in heat and humidity can lead to a broadening of the geographic range of a variety of insects, molds and parasites. Infestations are most dangerous to wooden artifacts and buildings, but can also affect fiber, bone, leather and fauna and flora remains. Many different organisms can completely weaken the cellular structure in wood causing breakdowns and disintegration. Mould in historic buildings becomes a public safety issue when those buildings are still in use and many regions have already considered this in their management plans.

In northern regions this will be a particular concern for areas that have never had to cope with infestation issues and do not have management plans in place (Jerome, 2007:193).

2.4.10 Solar Radiation

Ultraviolet light is naturally present in the atmosphere as a component of solar radiation. As greenhouse gases increase from the anthropogenic sources such as the burning of fossil fuels, the amount of ultraviolet (UV) light at the earth's surface also rises as it becomes reflected back to the surface of the earth in greater amounts. Ultraviolet light eventually causes deterioration in wood buildings and exposed artifacts in a process that begins on the item's exposed surface and progresses inwards. The deterioration is caused by hemicelluloses and lignin in the wood being attacked by the radiation and breaking down (Farrell, 2004). This is a significant problem, as wood is a widespread heritage building material. UV radiation is more of a potential hazard to exposed artifacts already excavated and contained in buildings than it is to the buried archaeological record (Cassar, 2005).

2.4.11 Wind

Archaeological sites located on exposed terraces or areas with thin sediment coverage are at serious risk from wind erosion. The severity and frequency of wind events is escalating with the increase in global warming. Arctic regions are particularly vulnerable to erosion of all forms, including wind, especially as many of the region's archaeological sites are exposed at surface level with zero or minimal protective ground cover. Wind erosion means the protective layers of sediment are blown away exposing artifacts to radiation, precipitation, waves and, in the case of northern latitudes, ice. It can also cause any sediments stirred up to be abrasive upon exposed artifacts (Blankholm, 2009:19). Wind also causes deflation in archaeological sites. Deflation is caused when small light artifacts and sediment are blown away leaving only heavier artifacts such as pottery, stone or metal jumbled together without their original stratigraphy. Deflation also scatters related artifacts in an unpredicted pattern and can also cause completely unrelated artifacts to be placed together (Kelly, 2010:61).

2.4.12 Extreme weather events

Extreme weather events such as hurricanes, tsunamis and cyclones are increasing in ferocity and frequency as sea temperatures and levels rise. The effects are catastrophic on both people and their environment. A well known example of such an event affecting cultural heritage is the impact of hurricane Katrina on New Orleans (a World Monument site) in 2005. Hurricane Katrina resulted in the failure of the levees around New Orleans, submerging 80% of the city for several days, in some areas for several weeks. This city is a cultural haven for architectural styles in many different historic districts most of which sustained intensive water and wind damage. In 2008 New Orleans was ranked in the top 100 most endangered heritage sites by the World Monuments Watch List (Kelley, 2007:224-227).

2.4.13 Tree re-growth

Tree re-growth can occur in several different circumstances such as farmland that is no longer being plowed or maintained or landscaping efforts on the part of land owners or townships. Trees, while beautiful and providing many environmental benefits such as cleansing the atmosphere of carbon dioxide and thereby retarding the development of global warming, can also wreak havoc upon buried archaeological sites in areas that have been free of trees since their inception. Tree roots can completely destroy the stratigraphy and features of an archaeological site causing the churning of artifacts and the complete destruction of feature such as hearths that become completely unrecognizable.

Forested areas are also a great deal more difficult to survey and record the location of sites. This is especially true in southern arctic regions where, due to the increased hospitability of the climate, in some places there has been a latitudinal movement of up to 100 miles northward of tree growth in the last thirty years (Blankholm, 2009:19).

2.4.14 Human expansion and resource exploitation

By 2050 it is estimated that up to 80% of the Arctic will be affected by human expansion and or resource exploitation (Blankholm, 2007:20). As technology increases along with demand for resources, a more hospitable Arctic environment is inviting more development. Developments can include urban centre expansion such as housing, mining camps, pipelines and oil rigs as well as dam building to create water reservoirs or to shore up rivers and lakes against flooding. Such human infrastructure development and resource exploitation is the greatest threat to the archaeological record worldwide; however in circumstances such as the circumpolar region, it is precisely the warming temperatures caused by global warming that are making development more inviting. The small island of Melkoya, Finnmark, Norway, before and after the creation of the Statoil LNG terminal, gives a dramatic example of the changes resource exploitation can bring to a fragile Arctic landscape and the complete destruction of any archaeological material. The entirety of the small island was converted to a refinery (Blankholm, 2009:20-21). Before work was conducted on the island the oil company financed an archaeological salvage company to excavate the three clusters of sites present on the island dating from the Early Stone Age around 10,000BP to the Iron Age around 1,500BP. Any sites that may have been missed are now completely gone from this archaeologically rich site (Ramstad, 2002:1).

2.4.15 Tourism

Tourism in the Arctic is increasing at a steady pace. With escalating temperatures and technology, accessibility of cultural tourism to previously inaccessible areas is increasing as well. Sites that do not have strict management policies, or have not even been recorded as of yet, will face a high level of damage from disturbance of the ground cover or even looting of artifacts. Archaeological sites in the Arctic are unique in that for the most part they are exposed on the surface with little to no ground cover. The ground cover that is on some sites is usually extremely thin, easily damaged and is effortlessly scraped away by the friction of trampling feet, leaving artifacts vulnerable to exposure and humans. Part of this increase is due to a greater accessibility to the land by the reduction of the far north. The opening of sea ice allows for cruise ships to have greater maneuverability and access, while the loss of ice on land exposes sensitive areas to visitors (Barr, 2009).

Now that the potential consequences of climate change on the archaeological record have been outlined, the next chapter will describe several examples in which these processes are already taking place, and how they are being responded to.

Chapter 3
Case Studies: Climate Change and Archaeological Heritage

3.1 International situations and approaches

Climate change affects archaeological sites in different ways depending upon location. Arid locations such as Australia or Greece face an escalating threat of wildfires. Coastal regions such as Great Britain are facing inundation and erosion situations, while far northern areas are rapidly losing their protective layer of permafrost. Below are descriptions of several places that are currently dealing with degrading environmental conditions and attempting to create contingency plans in their heritage management practices should the situation continue to deteriorate. Many heritage professionals throughout the world are already realizing that warming temperatures are not a distant possibility but a current reality. This is an excellent indicator that archaeological heritage legislation, plans and models need to be created in the near future in order to mitigate as much damage as possible.

3.1.1 Wildfires in Greece

Greece is a unique place when it comes to archaeological heritage. The entire country is covered with archaeological sites spanning thousands of years, from the above-ground built heritage of the Acropolis in Athens to buried Minoan sites on the Island of Crete. The present Greek national identity is almost inseparable from its archaeological past and its booming cultural tourism industry. However, Greece's archaeological heritage is actively threatened by the effects of global warming. In 2007 there were a series of heat waves followed by catastrophic wildfires in the area around the famous archaeological site of Olympia. Thanks to good planning, in 2004 a fire protection system had been installed prior to the Olympic Games, in the vicinity of the Olympia archaeological site, museum and Olympic buildings.

This enabled firefighters and volunteers to save this important international site during the 2007 fires, although the surrounding parks and monuments were destroyed. Fires in Greece are becoming a more serious issue due to longer and more severe heat waves and the resulting drying conditions of vegetation and soils.

Greece is creating a twenty year contingency plan in their legislation to deal with the fall out of global warming as the effects are predicted to intensify from current levels. To help combat the increasingly favourable conditions for wildfires, Greece has been increasing its manpower in firefighting forces. Land reconstruction and alteration is underway, such as planting traditional and fire-resistant forests in burnt areas versus the automatic insertion of a tourist resort. Water reservoirs are being constructed, satellite monitoring with the help of NASA is taking place, and the fire protection system is being expanded. Tourism in Greece is one of the primary sources of income for the government and the local communities. A threat to this economic livelihood is taken quite seriously and this is one of the few places in the world where a pro-active role against the potential effects of climate change on both the built and buried archaeological sites is being taken, and specific legislation enacted (Kolonia, 2007).

3.1.2 Bush fires in Australia

The national parks of Australia contain a large number of historic huts and settlements created by explorers, settlers and hikers moving across the continent in order to have shelter from the elements. Some of these shelters are mean huts whereas others were created for long term occupations. These buildings are protected under heritage laws as contributing significant value to tracing the settlement patterns of the country. There are also buried aboriginal sites and a number of significant rock painting sites. Australia is already observing changes derived from a warming climate and is developing possible scenarios upon which to base management plans.

These scenarios include an increase of up to 6.0˚Celsius, longer drought periods, heavier rain falls in the north and fewer in the south, with stronger storms, all leading up to a substantially higher number of days with a high bushfire potential. Fire is the main non-development threat to the archaeological heritage of Australia, and it has already taken a toll. In 2003 there was a massive wild fire that destroyed a number of sites in Australia's Kosciuszko National Park and surrounding lands and cities including the capital of Canberra. Included in this damage were nineteen small historical huts that were built and used by people working in the mountains or travelling through them. In the aftermath of the 2003 fires a number of sheds were restored that had documentation and the rest were left to deteriorate. The remaining huts are now undergoing a full documentation for future restorations if necessary. There are a number of plans underway to help meet this increasing threat, including raising awareness with various campaigns as to the sensitive nature of the sites and advice to tourists to avoid campfires. Australia has created a number of fire breaks near vulnerable areas and equipped a number of sites with firefighting equipment; they also have one of the most advanced emergency response plans in the world that includes minimizing property damage (Pearson, 2007).

3.1.3 Desertification in China and Mongolia

In the deserts and plateaus of China and Mongolia there lie many ancient and abandoned temples and settlements from past civilizations and smaller buried sites from nomadic peoples spanning the last 10,000 years. There are entire cities as yet unexplored, half buried under the sand. Desertification is a severe problem in arid and semi-arid regions for archaeological sites. Desertification can be caused by intensive human land use for agriculture which will destroy fragile soils. It can also be caused by intensive heat and extreme wind storms, or a combination of both. A warming climate is placing severe stress upon the chemical composition of soil, weakening its density and leaving it vulnerable to high winds. These winds are also increasing in intensity with the higher temperatures (Huang, 2009:56).

Shifting sands are capable of burying massive ancient cities, while extreme winds mixed with the sand are capable of pitting and wearing down exposed built environments until there is nothing left but dust. This is the case around the Ordos Plateau of Mongolia and China where mass desertification is taking place where sites date all the way back to the early Neolithic. In response, some governments in Mongolia are implementing vegetation policies. This involves the planting of millions of poplar trees, a 'green barrier' to arrest developing sand dunes. China uses an artificial method of creating sand barriers with small rows of wooden or rock fences. The main purpose of these sand barriers is to protect arable land for farming, but they also protect the built heritage of the region (Wang, 2009:1).

3.1.4 Coastal flooding – Britain

The coastal regions of Britain contain archaeological settlements from a diverse array of cultures, from the Druids, Norse, and Romans, all the way to remains from the First World War. Many of these archaeological sites are buried and invisible to the eye; a great many, however, are extremely visible cultural landmarks, such as the Tower of London built almost 1,000 years ago.

Coastal flooding and erosion is becoming a major concern among heritage professionals in the UK. With sea levels expected to rise almost a metre within this century and storms becoming more frequent and violent, island nations will be the hardest hit with these changes (Adams, 2007:194). Some regions will become completely inundated leaving salvage excavations, moving buildings or destruction as the only possible alternatives for archeological sites. Other areas will experience flooding and erosion, washing away the region's physical heritage.

One of the most visible and technologically advanced displays of flood prevention in the world is the Thames Barriers on the Thames River in London, England. This barrier was put into operation in 1983 to protect London from tidal floodwaters.

Although the preservation of heritage was not the primary intent of the barrier, it represents the only type of response likely to preserve built heritage in London's context. Unlike regions such as the Arctic with its low population density and minimal infrastructure, it would be physically impossible to relocate massive built heritage in heavily populated urban locales such as London, and therefore prevention versus reconstruction or relocation is paramount. The Thames barrier was to be utilized two to three times annually when initial planning and construction was begun; actual usage has more than doubled these estimates primarily due to increased quantity and ferocity of storms and tidal action (Egloff, 2007:200).

Erecting physical barriers directly in the path of archaeological sites is a relatively easy short term solution to potential flooding. The problem with this solution is that it will impede the flow of water and may amplify the affects of flooding elsewhere. Barriers can be cost effective depending on the material used such as sandbags or concrete, although they would need to be maintained and monitored on a regular basis. Barriers also have the added bonus of not altering or disturbing a site, although they do modify the natural landscape (Chapman, 2002:242).

3.1.5 York Factory in Manitoba

There are many archaeological sites in Manitoba, particularly historic sites near Hudson Bay involving the fur trade and colonization of western Canada. The largest and most important of these sites, York Factory on the Hayes river, is under serious threat from erosion and is estimated to be lost within approximately 100 years with the river experiencing an erosion rate of three metres per five years (Chapple, 2007:211). Two settlements closer to the river on the same site have already met that fate. Manitoba has several different climate zones; in the northern portion of the province where York Factory is, permafrost plays an important part in the terrain. The permafrost in northern Manitoba is being monitored and has experienced a rise of two degrees Celsius since 1993.

The active layer of permafrost is being constantly monitoring to watch the effects of the freeze/thaw cycle on archaeological sites, as the shifting ground can destabilize structures and destroy buried sites (Chapple, 2007:211).

Rising water tables and increased drainage of the land are escalating threats with the increasing temperatures. Parks Canada and experts in heritage management as well as geotechnical engineers in Manitoba are working together to design research and policies to address the complex preservation of sites such as York Factory. Amongst the possible solutions are the physical movement of the historic buildings to more stable areas of land, salvage excavations, thorough documentation both for research value and possible reconstruction, and possible solutions to stabilize the permafrost or slow the erosion such as with sandbagging (Olynyk, 2007:213).

3.1.6 Beaufort Sea coastal erosion

The coast of the Beaufort Sea is an area rich in archaeological sites. The region has sites dating back to the settlement of the Arctic thousands of years ago. For example, there are Thule sites, ancestors to the Inuit, historic hunting sites that are linked to the current inhabitants of local communities, and even old whaling sites (Maxwell, 1980). Erosion due to rising sea levels and thawing of the permafrost is a crucial problem for the local people and the archaeological record. The Beaufort Sea has an average rate of erosion of 5.6 metres per year since 1980 (Jones, 2008).

Around the coast of the Beaufort Sea high resolution spatial aerial photography is being used to monitor erosion rates. Rates of erosion can be predicted using aerial photographs taken over a period of several years that have been digitalized to provide a uniform baseline. These baselines can then be used to create general and site specific management plans. Management plans are created based on prioritization and immediacy of the threat, and are increasing documentation of sites as well as relocation plans for significant historic buildings (Jones, 2008:361-364).

3.1.7 Herschel Island

Herschel Island, Yukon is designated a Historic Settlement Area by the Canadian government, has a broad mix of cultural heritage from the 1000 year old Thule culture to an historic whaling outpost and is still used today as a base for traditional subsistence practices of local First Nations groups. Herschel Island has been placed on the 2008 World Monuments Watch List of 100 Most Endangered Sites, the only site in Canada to make this list (Yukon Historical & Museums Association, 2007).

The sea level around the Beaufort coastline in the Yukon Territory has risen 10 to 20 centimeters in the 20th century, and conservative estimates predict at least another 50 centimeters in the 21st century caused by global warming (Olynyk, 2007:212). The rising sea levels and temperatures are causing a significant level of erosion as well as a rise in storm and wave velocity. Herschel Island is rapidly eroding into the sea and is also being affected by permafrost movement and water-logging of historic buildings caused by a raised water table. Several of the historic buildings in this site were physically moved away from the coast as they were judged to be in immediate danger of eroding into the sea. Physically relocating important heritage sites takes a great deal of planning and finances, but will bring in a return culturally and financially in terms of cultural tourism for local communities. A determination of what to do with other components of the site such as the graveyard which is being destroyed by the process of solifluction (thawed permafrost causing the land to slump and move), has yet to be made. The plan to salvage this site and others will involve a high degree of monitoring and a staged time scale based on priority.

The Yukon government has put together a team that will use archaeologists, architectural conservationists and paleontologists to contribute to a heritage management policy for Herschel Island (Olynyk, 2007:213).

3.1.8 Fort Conger

On Ellesmere Island in Quttinirpaaq National Park, a historic 19th and 20th century site named Fort Conger is under duress from warming temperatures that are accelerating the decay of the buildings, increasing erosion of the coastline, and amplifying the freeze-thaw cycles of the permafrost which in turn destabilizes the buildings on the surface. Fort Conger was established in 1881 as a research station and was later utilized by Robert Peary as a base for his expeditions. The national parks of the Canadian Arctic are one of the few places the Federal Government of Canada, or Parks Canada, is taking action on archaeological sites threatened specifically by global warming. The Arctic is a place where environmental threats outweigh the severity and immediacy of infrastructure development. The problems and changes caused by increasing temperatures will be most dramatic and potentially devastating in the far north; however the potential to observe and protect the threatened sites is also the most practicable as well since they face the least threat of human trespass. Parks Canada is currently utilizing new laser scanning technology to develop a 3-D interactive plan of the site for archival and presentation purposes. This is one of the first attempts in North America to use this technology as a preservation and monitoring technique.

The decision on which actions should be taken to mitigate the decimation of the site has not yet been made as there are also environmental concerns. As a historic site, there are possible contaminants that may be exposed to the sensitive environment around the site if it continues to degrade (Parks Canada (b), 2010).

3.1.9 Ice Patches

Ice patches are areas of high altitude in the northern regions of the Yukon, Northwest Territories and Alaska where caribou would go to escape the insects and heat of summer. These were therefore prime locations for prehistoric hunters to locate their prey. The ice patches in the Territories are revealing fragile organic artifacts, as the ice melts due to global warming, dating back over 8000 years. These artifacts are providing important links in occupation patterns for researchers. For example the development from hunting with spears to the transition to the bow and arrow is clearly illustrated in the recovered record. The preservation of these sites is due to periodic snow coverage and subsequent freezing of these patches. As the patches melt melt with the warming climate, the vulnerable artifacts begin to degrade as soon as they are exposed on the surface. To protect the exposed artifacts, involvement of local First Nations groups is crucial in order to obtain the necessary human resources required for the salvage of any artifacts from these sites. There is very limited time to collect the artifacts before deterioration, and therefore archaeologists and First Nations leaders are cooperating to create science camps, surveys and community research projects to reach as many artifacts as possible, as well as inviting elders to record local traditions and lore (Hare, 2004).

3.1.10 Altai tombs

The Altai Mountains span four countries, Russia, Mongolia, Kazakhstan and China. They contain an archaeological history of almost six thousand years. The most prominent of the civilizations represented, are the Scythians, a nomadic, artifact rich, tribe of horsemen, who faded from the archaeological record around 1500 years ago. Most of this material history is contained and protected within the tombs of many different nomadic peoples buried deep in the permafrost of the mountain valleys and under local glaciers. The protection of cold and permafrost creates an ideal environment for the complete preservation of the tombs including the corpses and grave goods – organic and non-organic. However, much as in the Canadian Arctic, the temperature in the Altai region has been increasing at a higher rate than the global average with a mean decadal rise of 0.6˚ Celsius. The glaciers have been retreating at a rate of 9-20 metres per year. The last century has seen a loss of 27% of the mass of the glaciers and it is estimated that the 21st century will see the complete disappearance of any glaciers in this region (Bourgeois, 2007:461).

With the increasing physical accessibility of the area, demands for resource exploitation such as oil pipelines and for eco-tourism destinations are also increasing. The scale of the risks to and the potential archaeological value of the Altai Mountains is such that UNESCO has set up and provided a grant for an inventory of the tombs, an evaluation of the permafrost to determine the immediacy of the threat to each individual tomb, as well as an effort to test solutions to preserve the permafrost and do any necessary salvage excavation for those that cannot be protected (Borgeois, 2007:463).

To create an accurate inventory of sites and maps of the area, satellite images, aerial photos and physical surveys done by various partners are being combined to demonstrate that it is possible to create an archaeological survey of a vast landmass with appropriate technological and human resources. Between 2003 and 2006 a total of 8770 monuments were documented to add to the 330 previously known ones which correlated to around 870 sites.

The information provided by the survey alone has provided tremendous knowledge of the archaeological landscape, the movements, and land usage by an array of peoples (Bourgeois, 2007:469). In 2005 and 2006 two field seasons were conducted that allowed for the testing and modifying of survey and mapping models. All data was plugged into a database called ALTARI that recorded the various levels of the finds such as burial level or an individual above-ground structure and then linked to geographic information system (GIS) software ArcView and ArcMap to create various maps or other valuable information (Bourgeois, 2007:468).

The identified frozen tombs are to be monitored using ground temperature monitoring to determine if any are thawing; if this happens then further approaches will be taken to preserve them. The main determinant to the depth and strength of the ice lens encompassing the tombs is the height and thickness of the stone debris mound on the surface. The simplest way to preserve the tomb would be to enlarge the protective stone layer; however, that would be altering the site itself which has been determined to be unacceptable. A second possibility explored by the team was to provide shading or a covering over the burials which lowers ground temperature anywhere from 3 to 7˚ Celsius. This solution was also ruled out due to the visual disturbance to the land (Bourgeois, 2007:470).

The model deemed to be most suitable is to use thermosyphons (these will be discussed in more detail in the following chapter) to decrease and maintain the sub-surface temperature and preserve the permafrost (Bourgeois, 2007:470). Thermosyphons are a desirable method of stabilizing archaeological sites preserved in permafrost as there is minimal visual disturbance to the landscape.

The case studies above are all examples of the broader issues and responses of the threats of global warming upon archaeological sites. In the next chapter, this information will be used to evaluate a very specific situation in order to demonstrate the minute considerations and the possibilities that are involved in preserving our heritage in the face of climate change.

Chapter 4
The Practicalities of Preserving Arctic Archaeological Sites Using Sannirut as a Model

4.1 Arctic archaeology and global warming

Even though the case study of this chapter will deal with only one archaeological site, the issues explored are relevant to a large number of sites. Almost 40% of Canada's landmass is in the Arctic regions, the location seen to be the most impacted by global warming. These two factors make it crucial to develop policies and practices to stabilize the future of the Canadian Arctic's archaeological heritage through a warming climate.

As is the case elsewhere, warming temperatures in the Canadian Arctic affect archaeological sites through an increase in precipitation, increased storm and wind velocity, melting permafrost and less protection from sea ice, all leading to increased erosion and exposure. Various types of sites are affected in different ways. Historic sites such as Beechey Island-which among other things has material culture from the Franklin expedition (Powell, 2006)-contain wood and metal objects that are being affected by warmer temperatures and precipitation by an increase in mold, rust and rot. It is probable that buried archaeological sites are being lost by the hundreds every year through erosion and turning of the soil through new or more extreme freeze-thaw cycles of permafrost. The erosion in many places along the coastline can be as dramatic as a loss of several metres annually such as at the well documented Saatut site on Baffin Island. The Saatut archaeological site, which can trace 2000 years of Arctic history including that of the Thule people, is eroding away quite dramatically by several metres per year and will be gone completely in a number of years (Mary-Rousselière, 2002). This erosion is a major hurdle in site preservation as most human activity past and present in the Arctic is centered on bodies of water. Global warming is also making accessible the previously inaccessible. Eco-tourism and cultural tourism are booming industries that are only predicted to grow.

Tourism is potentially damaging to archaeological sites through foot traffic and looting as well as the damage or removal of protective ground cover. Tourism can, however, prove to be lucrative to local communities and to fund site maintenance, surveys, and periodic monitoring of the condition of sites. A prime example of this is the Arctic cruises that include an archaeological program, such as those offered by the company 'Adventure Canada.' These make stops at archaeological sites complete with an archaeologist and an Inuit elder to guide tourists and provide security for the site. These visits allow for documentation of site conditions as well as any new sites found (Rast, T., 2008). Education of tourists and detailed management plans can alleviate the negatives of tourism by contributing important documentation to threatened sites (Barr, 2009:148-149).

4.2 Sannirut

4.3 Why is Sannirut special?

The Arctic archaeological site Sannirut (formerly referred to as Button Point), Borden reference designation of PfFm-1, is located on Bylot Island just off the north coast of Baffin Island about 40km from the community of Pond Inlet (Park, 2008). It is significant for a multitude of reasons, chief among them the high level of preservation of wooden artifacts. Two of the most notable archaeological finds in the Arctic from the Dorset period are two life-sized wooden masks dated A.D. 500-1000, that were excavated from Sannirut (see Figure 2). No masks of comparable age have been found elsewhere in the Arctic.

Figure 1. Map showing the location of Sannirut, Bylot Island in Nunavut, Arctic Canada (Park, 2008).

Figure 2. Life-sized wooden Dorset masks from the Sannirut site, Bylot Island (Redrawn by, Park, 2010).

The material culture contained within the site encompasses the entirety of the human occupation of the High Arctic, beginning approximately 4400 years ago with the Independence I and pre-Dorset cultures who migrated to the High Arctic from Alaska. Around 2800 BP the pre-Dorset went through considerable changes and became known as the Dorset culture. The Dorset thrived for a number of years but by A.D. 1000 they too had virtually disappeared from the Arctic landscape.

It is around this time that the ancestors of the Inuit, the Thule culture, migrated into the Arctic from the west. The Thule material culture was significantly different from the ones preceding and was a highly successful adaptation to a warming environment focusing on marine hunting in open waters. It is quite likely that the warming and cooling periods played a substantial role in the development and disappearances of Arctic cultures. For example the warming period around A.D. 800 may have placed stress upon the Dorset peoples who were more closely adapted to a colder climate and depended upon the sea ice for survival (Park, 2008).

Only a portion of the peninsula on which the Sannirut site is located has been excavated, leaving large portions of untouched stratigraphy-in some areas perhaps up to a metre deep with the potential to allow deep and meticulous research into the culture changes of the Arctic over time. Archaeological excavations began on Sannirut in 1923 headed by Therkel Mathiassen. The majority of excavations there, however, were conducted by Father Guy Mary-Rousselière over the decades of the 1960s into the 1990s with the majority of the excavations taking place in the early portion of that span. Father Guy Mary-Rousselière was a Catholic priest who lived in Pond Inlet on Baffin Island and did work on many different sites in the region. He was also the first to make observations on the deteriorating condition of Sannirut as early as the 1970's. Brief visits to the site were made by archaeologists Patricia Sutherland in 2000 and by Douglas Stenton and Robert Park in 2004, and they also observed changes in the site (Park, 2008).

4.4 Physical description of Sannirut

Sannirut is approximately 250 metres long by 100 metres wide according to Guy Mary-Rousselière's archaeological permit reports. The artifact layer is between 40 cm and one metre thick, contained in a layer of peat, turf and soil lying on a base of stable permafrost consisting of clay and ice followed by the solid bedrock of the peninsula. The peninsula averages seven to eight metres above sea level and is attached to Bylot Island by an isthmus about 60 metres wide (see Figure 3), (Mary-Rousselière, 1973).

Figure 3. Sannirut from the air, viewed from the south (Park, 2008).

Figure 4 illustrates slumping at Sannirut and underscores the immediate danger of this site eroding into the sea as its embankments continue to degrade.

Figure 4. Slumping archaeological deposits at Sannirut (Park, 2008).

4.5 The issues

For 4500 years the artifacts at Sannirut have accumulated and been remarkably protected in the body of peat and permafrost. Based on the level of preservation of the wooden artifacts, the site would have needed to be environmentally stable for at least the last 1000 years. The threats to the site as far as we can ascertain only began in the 20th century coinciding with the human-induced phenomena of global warming. Guy Mary-Rousselière started noticing and recording annual deterioration starting in the 1970s in his reports on Sannirut. If the site had been deteriorating at present-day rates prior to the 20th century, there would be nothing left of the site to be concerned about (Park, 2008).

The average annual temperature of much of the Canadian Arctic has been steadily increasing at about twice the rate of the rest of the world over the last few decades and is only projected to increase (Barr, 2007:203). Figure 5 below shows the average increase in air temperature for Pond Inlet, Nunavut which is the closest community to Sannirut.

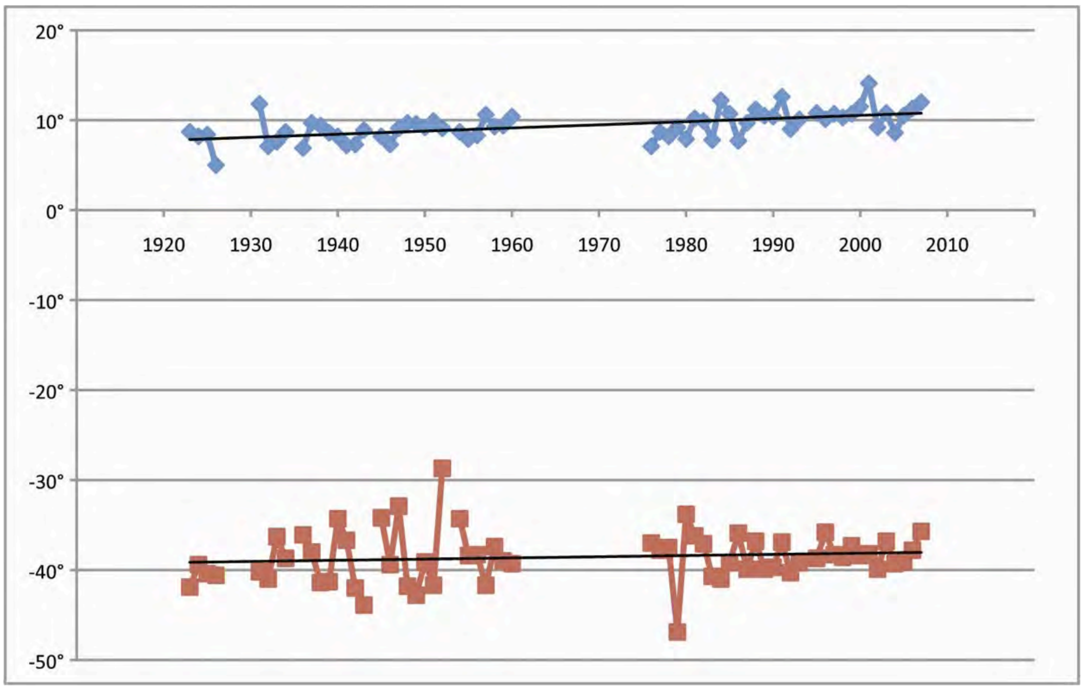

Figure 5. Annual maximum (blue) and minimum (red) temperatures recorded at Pond Inlet. Data from the Canadian National Climate Data and Information Archive (www.climate.weatheroffice.gc.ca), accessed on August 26, 2010.

With the increase in temperature each year the level of thawing of the permafrost reaches deeper increasing the degree of water pooling and land displacement. The projected depth of the non-active layer of permafrost thaw within the next three decades is 0.85 metres, and since the maximum estimated depth of the artifact layer is one metre this will eventually expose almost the entire archaeological record of the site to some level of thawing (Bailey, 2009:19). The results can be seen in Figure 3, which was taken at Sannirut taken in 2002. The white objects are faunal bones which have been exposed to the elements.

As more and more of the land thaws and slumps away along the embankment it exposes the intact permafrost to the thawing effects of the warmer air in a vicious cycle. A decision on the fate of Sannirut will need to be made soon if we want to preserve the contents of the site, and this decision may influence further policy developments on other Arctic sites that are facing similar threats.

4.6 Logistical difficulties and considerations for the preservation of Sannirut

There are several considerations to be taken into account before any archaeological work can be done in the Canadian Arctic at Sannirut or elsewhere. The first consideration is support. Even with public and governmental technical and financial support the Canadian Arctic can be an extremely daunting locale in which to put an archaeological project into operation. The sheer vastness of the landscape makes it a monumental task to conduct a comprehensive archaeological survey. Many parts of the Canadian Arctic have not yet been surveyed in detail, yet the number of archaeological sites already recorded (not necessarily documented or researched) is staggering, as illustrated below (Figure 6), for Nunavut. Further, the number of known and recorded sites is likely only a fraction of what may exist (Park, 2008). The large number of sites potentially at risk makes prioritizing research extremely important and may come to mean that sites deemed to be in the most immediate environmental danger will receive priority over sites deemed to be in stable condition.

Money is a large part of necessary support in the undertaking of Arctic study. It is exceedingly expensive to conduct fieldwork in the Arctic–transportation, shipping, and accommodation are important considerations and work is usually only conducted through extensive grants and support. The cost of shipping of materials from southern Canada up to the closest community (in this case Pond Inlet), is approximately $10 per kilogram.

Between Pond Inlet and Sannirut any materials would need to be transported by helicopter adding further expense (Park, 2008).

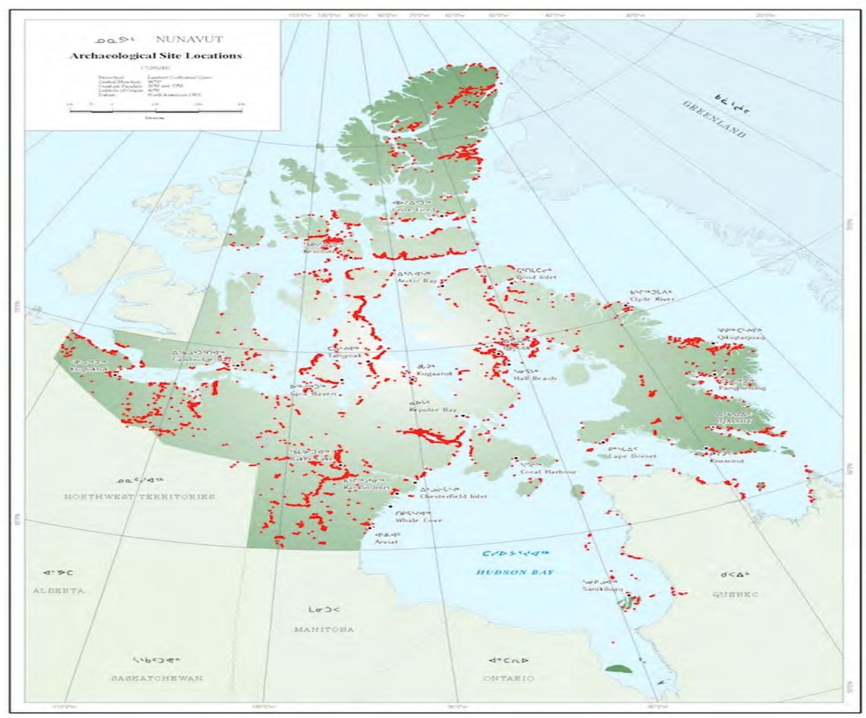

Figure 6. Registered archaeological sites of Nunavut, Canada (Department of Culture, Language, Elders and Youth Nunavut (CLEY, 2010).

Another challenge is the average length of time available each year for field projects. The inclement weather of the far north is a fundamental factor of archaeological fieldwork of any kind. There are usually only a few months of the year when it is possible to survey and even less to do excavation of thawed ground. This means that time is finite for researchers and work must be constrained in the reality of what can reasonably be accomplished in a given time period.

As much as possible a site must be returned to its condition prior to excavation. Work must be undertaken to be as minimally intrusive on the landscape as possible according to the Nunavut permit system. Sannirut is also still used by local Inuit hunters and access must not be restricted (Park, 2008).

There are also moral and ethical considerations by a number of different stakeholders. Direct Inuit involvement in the development and implementation of heritage management policy is both desired and incorporated into the legislation. Communities are to be informed of any local projects and community members must be offered the opportunity to participate (Stenton, 2003).

4.7 Possible alternatives

4.7.1 Benign neglect

One option for the future of Sannirut is to let nature take its course. Benign neglect is an approach that is taken in many archaeological sites. In many cases neglect is really the only option available. Not every site ever created can be preserved, and no site can be preserved indefinitely. For example English Heritage and the National Trust in England has declared several sites such as Blakeney Chapel, a Roman cemetery and several other sites as beyond any salvage efforts as they face "inevitable destruction" from the sea (Milmo, 2007:2). For significant sites, or a portion of sites needed to represent different cultures, benign neglect is not a reasonable choice if it can be avoided. Sannirut is both a significant and representative site. If the choice made for this site is to limit any intervention, Sannirut will continue to erode into the sea. Yet the importance of Sannirut suggests that this is not the most desireable alternative.

4.7.2 Salvage excavation

Salvage excavation is a standard practice for archaeological sites facing immediate and unpreventable destruction such as incoming housing developments or a complete breakdown in the surrounding environment. This would involve excavating the entire or majority of the site to recover any artifacts and context possible. A certain degree of salvage excavation will be necessary for Sannirut regardless of which approach (apart from benign neglect), will end up being the most feasible one. A full scale salvage operation, however, is both undesirable and impractical. Sannirut is a very large site of approximately 2.5 hectares with the coastal embankments alone spanning more than 500 metres. An excavation of this magnitude would be extremely time consuming and expensive, requiring many field seasons to accomplish and would not have the desirable outcome of leaving portions of the site for future archaeologists and future techniques to discover.

4.7.3 Snow fences

A possible solution to increase the permafrost stabilization of Sannirut would be to install snow fences around the perimeter of the peninsula. Snow fencing would inhibit the accumulation of snow on the site over the winter thereby decreasing the insulation against the bitter cold of winter. Without the insulation of snow the cold can permeate the ground to deeper levels and help prevent thawing. A study of the effects of snow fencing, permafrost destabilization and thermokarst conducted over six years in the 1990's in Barrow Alaska has demonstrated that soil beneath the insulating snow was on average between 2 to 14° Celsius warmer in the winter than the soil without snow cover. Less snow cover was also found to decrease the volume of water pooling on the ground when the snow melted. The ground beneath the snow blanket experienced between 10 and 20 centimetres of permafrost subsistence caused by the sitting pools of water and the warmer soil temperatures (Hinkel, 2006:350).

There are however several difficulties in implementing this solution at Sannirut. One of these is the fact that, because the site is still used by local Inuit hunters in the spring, fencing off the area would not be conducive to sustainable land use for the people and could also be seen as a blight on the landscape, as archaeologists are required to return the land to its original appearance as much as possible. There is also the logistical issue of transporting the fencing to the site. Fencing is heavy and bulky and would have to be transported from a fair distance. Estimated shipping costs run around $10 per kilogram making this a fairly expensive option. Extensive research into wind patterns and winter snow fall would need to be conducted in order to place the fencing appropriately so that adverse effects of additional snow are not created.

Snow barriers made of local materials might be more feasible if something could be created; however, an alternative solution to metal poles anchoring the fence would also need to be devised as the metal itself can become a heat conductor drawing the heat further into the permafrost. Plastic fencing woven through thermosyphons (to be discussed below), could be tested on a small portion of the site to determine if it would be a viable option for the long term preservation of the permafrost.

4.7.4 Thermal blanketing

Increasing the albedo (reflectivity) of the ground surface decreases the amount of solar radiation absorbed, thereby preventing an increase in soil temperatures. This can be done by blanketing the ground, creating a thermal barrier. White or light coloured material is most conducive to reflection and there are various ways to disperse the colour onto the surface of the Sannirut site. Any material can be used such as white sand, crushed stone or even white paint (although I have not found any examples of this being used).

Materials such as plastic, wood or metal to create a cover or shelter off the ground can also prove effective, as shown by experiments on the Qinghai–Tibet Plateau where several of the above methods were tried in the creation of a new rail road on land consisting of ice-rich permafrost. It was found that the soil underneath off-the-ground, shed-like structures was on average 8°C cooler than the ground that experienced direct solar radiation (Cheng, 2005).

The benefit to experimenting with this technique is that this approach is relatively non-intrusive, except to salvage areas of the site that are already slumping away; this method would only involve surface application. The disadvantage of this type of preservation is that it involves altering the physical appearance of the landscape by changing the colour or the actual material of the ground cover, with the possibility of causing environmental damage through the use of paint. The local community of Pond Inlet would need to be involved in future monitoring and maintenance such as adding stone, or touching up paint or repairing material, although any approach will require at least periodic local participation. There is also the unknown effect these changes would have upon the local wildlife as well as the vegetation; a layer of material blocking the sun over the peat could possibly irreparably harm the tundra material, as well as doing little to strengthen the slopes that are already slumping. A different type of thermal blanketing without many of these drawbacks is discussed below.

4.7.5 Polyurethane foam insulation

Another alternative for the preservation of Sannirut is an application of polyurethane foam insulation along the edge of the embankments. Polyurethane is a chemical polymer that, when sprayed onto a surface, has an exceedingly high porosity which means that is has a very low thermal conductivity– 218 times less than the frozen loamy sand of the site (Bailey, 2009:42). The thermal layer would provide enough insulation to substantially reduce the depth and duration of the permafrost thaw.

The bonding of the polymers also has a high probability of increasing the slope stability by binding the areas in immediate danger of slumping with the more stable horizontal surface layer. By at least partially covering the surface with the foam or any other material, wind and rain erosion should also be reduced (Bailey, 2009:49).

The polyurethane foam is stored in compressed containers allowing for less bulk in shipping and is applied with a simple spray nozzle allowing ease in training an assortment of people on how to apply the foam. The foam will last an estimated 30 years and can be easily re-applied when maintenance is needed or reapplied completely on top of any remaining foam. The foam is organic and will eventually disintegrate completely due to micro-bacterial processes and UV radiation if not reapplied and therefore will not cause permanent environmental damage.

This process has been tested in the field in stabilizing the permafrost around the oil pipelines of the Prudhoe Bay Waterflood project and the Norman Wells Pipeline in Alaska with successful results in preventing thawing of the permafrost as well as soil slumping or heaving (Bailey, 2009:43).

The most effective and efficient use of the foam would be to line the 400 metres of the embankment with a four metre width of spray 1.5 centimetres deep, 60 centimetres on either side of the edge allowing for adhesion of the slumping edges as well as preventing vulnerable areas from being exposed to thaw (Bailey, 2009:47). See Figure 7 below for the estimated application area.

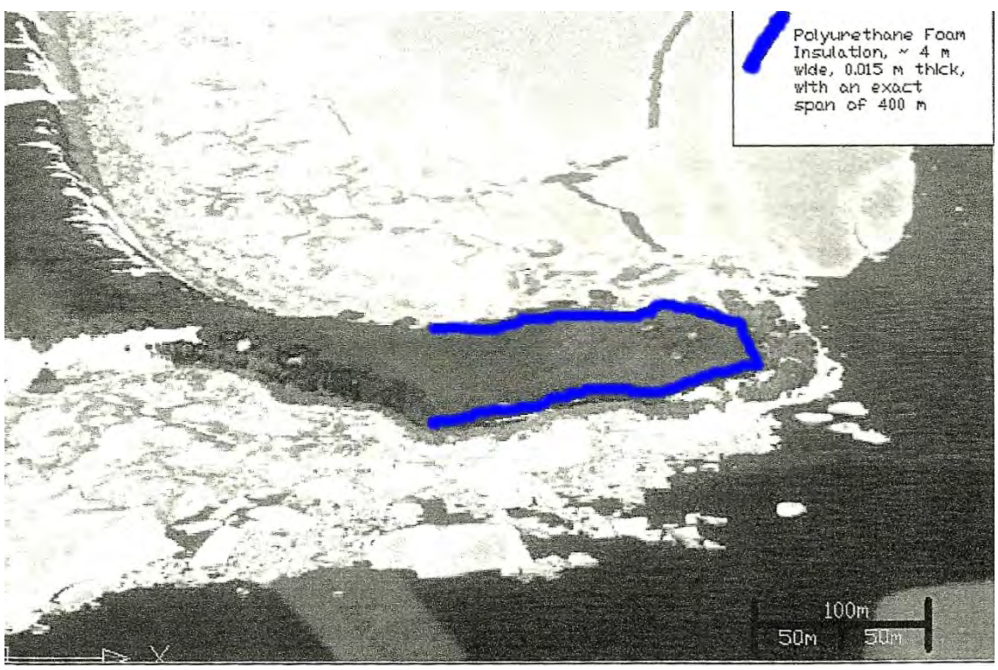

Figure 7. Site overview of estimated necessary Polyurethane application area (Park, 2008, redrawn with polyurethane application area by Pauline Goetz).

The financial costs of this method are significantly less than the thermosyphon network (see below). The total costs estimated by Brennan Bailey of the University of Waterloo's Environmental Engineering department who conducted the study on the feasibility of this method works out to $27 800.00. This amount includes the shipping of the three barrels of polyurethane foam, the material itself, and all applicator material. In terms of labour it is also time efficient, most likely working out to only one day of work by one person (Bailey, 2009:50). A potential problem arises in terms of possible damage that could come from artifacts exposed on the surface of the site that would come into contact with the foam. It is possible that damage could result as well as presenting difficulties in removing the material from the artifacts. Buried materials do not face a threat as the polyurethane is too solid to seep below the surface (Bailey, 2009:43).

4.7.6 Thermosyphon network

Installing a series of heat pipes or thermosyphons to create a network in the Sannirut site is a possible alternative for controlling the breakdown of the permafrost. Thermosyphons typically take the form of a pipe (length depending upon need), containing a fluid designed to evaporate when any heat from the surrounding permafrost is absorbed into the pipe; the fluid can be ammonia, propane or carbon dioxide. The evaporated heated fluid then travels to the top of the pipe were the air temperature cools it and the cold fluid condenses to the bottom of the pipe again. This results in a constant drawing of heat out of the permafrost while maintaining a constant cool temperature around the buried portion of the pipe.

Thermosyphons are an effective and tried method of stabilizing permafrost, often used in construction of pipelines and buildings. When used with carbon dioxide they present no risk to the surrounding environment and require little maintenance. They are mainly buried and so present a minimal blight on the landscape. They do however present some serious drawbacks as a sole method in the preservation of the archaeological record at Sannirut. The thermosyphons must be positioned 2 metres apart to be fully effective and with a minimum of 400 metres of embankment to protect that would require at least 200 of the units. The pipes would need to be a minimum of one metre long which at 2009 prices would be approximately $200 per unit for a total of $40,000.00. They would weigh approximately two kilograms each, adding an additional $8000.00 at minimum in shipping costs (Bailey, 2009:45).

Another issue that would need to be addressed is the possible damage that could be incurred to the archaeological record. The pipes are approximately two inches in diameter but with 200 pipes needing to be inserted in the ground to a one metre depth, a post hole digger would be necessary and possibly destructive as well. The pipes are durable and do not require an onsite presence, but repairs to a damaged unit could not be done easily or locally (Bailey, 2009:45).

Thermosyphons may be a good partial to the problems at Sannirut. A thorough study of the site may point to a few areas that are especially weak or are critical points to stabilizing major sections of the site, these areas present an appropriate place for thermosyphons to be placed in conjunction with other methods such as a polyurethane foam insulation blanket as described above.

A second alternative would be to do a salvage excavation of the perimeter of the site - in other words, to the portion of the site that is in immediate danger - and then placing the thermosyphons in the backfill of these areas. This would eliminate the danger to any artifacts through post hole digging and work to counter the detrimental effects of excavation on the permafrost.

4.7.7 Monitoring solutions

An important component of the preservation of Sannirut will be monitoring of the surface and ground temperatures as well as the condition of whichever methods are chosen for permafrost preservation. A first step will be to establish baseline numbers during the initial survey or setup of the site. With these numbers it will be possible to track the effectiveness of preservation methods used. Again, the data below was obtained from the University of Waterloo's Environmental Engineering department.

Thermistors are an effective way of measuring ground temperatures and thaw mitigation systems of the permafrost. A thermistor works by passing an electric current through a conductor (a long cable with a probe on the end), that measures resistance and converts that resistance into measurements of temperature by a datalogger. The thermistor which would be most effective for Sannirut is the *Campbell Scientific™ probe 107B.* They are designed for rugged Arctic environments and have a design life of ten years with a cable length of 300 metres which is necessary for the length of the site; the next closest unit only has a 30 metre cable. The probes can be set at 50 metre intervals requiring eight units.

Air temperature and humidity readings are also an important monitoring component and can be done with a probe from the same supplier which will bypass any complications of programming. The instrument itself is called the HMP45C212. The probes are all protected from long term exposure and will take periodic measurements without human involvement. The instruments utilize solar power with a backup battery and the data can be transferred remotely from a computer, cell phone or satellite. There are other sensors such as the HOBO Micro Station Data Logger that function in much the same way if initial testing turns up poor results with the suggested equipment.

The total initial estimated costs of implementing the proposed monitoring plan with ground and air probes would be close to $6000, with possibly up to $20,000 more involved in maintaining and replacing equipment for up to 30 years (Bailey, 2009:40).

Soil samples will also need to be taken and preserved in a frozen state to be analyzed for ice content and exact composition in order to create a better model and adjust any implemented systems if need be (Bailey, 2009:34).

4.7.8 Multi-dimensional solution to Sannirut

While Sannirut may be a dynamic, unique site rich in culture and research potential, the environmental situation it is in is not unique at all. There are archaeological sites throughout the Arctic facing mounting challenges posed by global warming – many experiencing escalating vulnerability of their permafrost protection. If an efficient and effective means of stabilizing Sannirut can be found then that model can be replicated elsewhere. A time will come when governmental policies are developed that account for preservation of sites facing threats from global warming and a precedent will have already been set that can be used as a guideline.

I do not believe a one-strategy-approach would be most effective at Sannirut. I would suggest a season of experimentation of the above approaches first to determine the effectiveness of each. Multiple seasons, 2 or 3, would be desirable if resources allowed for it to test the effectiveness of as many methods as possible as well as to allow for any technical problems.

A certain amount of salvage excavation is going to be necessary for areas of the site that have already broken away and the artifacts within are already beginning to slump to the bottom of the embankment and are in danger of being washed away by ice or waves. The provenience and stratigraphy of the artifacts will most likely not be recoverable, but the artifacts themselves would be salvaged. Thermosyphons could be used in key and critical areas only-a thorough survey of the site would need to be done to establish these points. The criteria would be areas that are extremely unstable, are experiencing a higher level of permafrost thaw than the rest of the site, or are key points that could contribute to stabilizing a large area of land. Alternately, thermosyphons may be found to be the most effective strategy in which case I would suggest placing them in the back-filled areas allowing for an easier time of installation and less possible damage to buried artifacts. One of the most intriguing possible preservation methods would be a coating of polyurethane foam spray around the perimeter of the embankment to prevent thaw and stabilize the slope. This would be done after a thorough survey and surface collection was done to eliminate the possibility of the foam damaging any exposed artifacts.

These methods together should ensure decades added to the life of Sannirut, time that allows for new developments and thorough research or excavation if need be. With the massive volume of sites in the Arctic and the rate at which the effects of global warming are being felt on them, time is a very precious element and a method or methods to stabilize them can be key to allowing a certain degree of *in situ* preservation of the archaeological record.

Chapter 5
The Heritage Context for Preserving Sannirut

5.1 Heritage

Society has placed importance on the physical links to where we have been and what we have accomplished – on the artifacts and archaeological sites created by humanity in all its civilizations. These links are used to foster knowledge and understanding of different peoples around the world to each other. They are used to create economic benefits to local communities through cultural tourism and employment opportunities. They are ties to cultural heritage for descendent communities to maintain their own traditions and even relearn ones forgotten. Archaeological heritage can provide tangible evidence in a court of law for Inuit and First Nations land claims as well as invite active participation by all members of society in moving the fields of archaeology forward in a socially conscious manner. The importance of archaeological heritage has been acknowledged, and so to must the threats to it.

Henry Chapman (2002:242), of the University of Hull, England has suggested that the reasoning behind the woefully inadequate attention paid to climate change on the part of archaeological heritage management practitioners is due to more immediate and pressing triage concerns such as infrastructure development, as well as the apparently long timescales involved for threats from rising temperatures. Threats that develop on a predictable visible pattern and timeline (such as a proposed highway), are much easier to predict and act against than a debatable global menace that may, or may not, wreak havoc on the archaeological record (Chapman, 2002:242). While the above concerns are valid they do need to be re-evaluated. Land development may be a more immediate pressure but the increasing environmental instability poses sudden and sometimes catastrophic threats to archaeological heritage.

The long timescales have now become immediate realities and the science behind a global warming trend has been acknowledged with widespread acceptance.

Protecting and managing archaeological heritage can mean different things depending on the party in question, whether it is feuding political parties, First Nations communities, developers, academic archaeologists, etc. No matter which group is involved or being appealed to, the factors of money, manpower, interest, immediacy of the threat, and environmental conditions must be taken into consideration. There will never be enough financial or human resources to protect every archaeological site in North America, let alone globally. Choices will always have to be made as to which sites can or even should be preserved and it will come down to archaeological sites with the least amount of conflict to preservation and the greatest return benefits that will take precedence in preservation efforts in heritage legislation.

5.2 Heritage legislation

5.2.1 Why discuss heritage legislation?

> *"Archaeological heritage is an essential element in the affirmation of our Canadian identity and a source of inspiration and knowledge. It is the policy of the Government of Canada to protect and manage this heritage."* (Archaeological Heritage Policy Framework, Department of Canadian Heritage, Ottawa, 1990, http://www.pc.gc.ca).

Heritage legislation is important to mention simply for the reason that it an already existing legal structure for the protection of archaeological heritage. There is a political framework in place that acknowledges and legalizes the place and importance of physical heritage to the people of this country. It is within this framework that measures can be taken to deal with the heritage challenges of global warming. It is important to acknowledge and repair the gaps in heritage legislation. There is no official legislation currently in place dealing with heritage management and climate change in Canada.

5.2.2 Reasons for the climate change gap in heritage legislation

In Canada there has never been an over-riding umbrella of federal regulations concerning the preservation and management of archaeological sites and the material recovered from them (Ferris, 2000:168). The independent control of ten provinces, three territories and Parks Canada covering national parks, over Canada's archaeological heritage poses a unique situation amongst developed nations, along with challenges that are not homogenous across the nation–politically or environmentally.

There appear to be three over-riding reasons for climate change having not already been incorporated into heritage management legislation in Nunavut, or Canada for that matter. The first of these is the sheer time scale involved in global warming predictions, from decades to centuries before some consequences will be felt. Most legislative planning is simply not done for that space of time, political terms are short and long range plans with minimal short term payoffs are not necessarily popular. The second reason is financial resources. Funds for heritage management have been decreasing in recent decades and it will take a serious allotment of money to adequately prepare any significant number of archaeological sites to withstand the onslaught of a changing climate. The third issue is uncertainty. There can be no guarantees that the predictions global warming models make and the scenarios outlined by bodies such as the IPCC (Intergovernmental Panel on Climate Change), will become reality. Therefore it is simpler to deal with immediate certainties and leave the models for when they become reality.

5.2.3 Nunavut legislation

A very large portion of Canada's circumpolar region falls within the Territory of Nunavut's borders, including the Sannirut site on Bylot Island. An understanding of the context and heritage legislation of Nunavut is important to the success of any preservation efforts.

Archaeological assessments in Nunavut are required before any development can take place on Territorial land, which was put into law with the land claims agreement that led to the creation of the Territory of Nunavut in 1999, and was also a part of the original proposal put forward by Inuit leaders two decades earlier in 1976 (Suluk, 2008:62). More than 85% of the 30,000 people living in Nunavut are of Inuit descent, and it is the Inuit who were in the forefront in developing the creation of their homeland within Canadian politics (Nunavut Tunngavik Inc., 2008:9). Article 33, of the Nunavut Land Claim deals specifically with archaeology and the rights and responsibilities of the Inuit people and the government to care for and manage the archaeological record. It is mandated in the Agreement that the Inuit Heritage Trust (a panel of Inuit) be invited to participate in the creation of any heritage management policies as well as having full access to any records or databases from government sources that are conducting archaeological work in the Territory. In addition to this, all archaeological materials found within Nunavut belong jointly to the Inuit Heritage Trust and the Nunavut government provided they are not recovered on land under Parks Canada jurisdiction.

It is also mandated in Nunavut that contracts will be given preferentially to any Inuit heritage management company provided they are qualified; employment within those contracts should also be given to local Inuit if possible (Nunavut Tunngavik Inc. 1999). This is an important component of the legislation as it is a crucial part of any long term preservation plans' success. The training of local people to monitor sites and perform any necessary maintenance to preservation equipment will determine the fate of many archaeological sites in Nunavut. The ties and involvement of the Inuit in archaeology will only serve to promote preservation efforts.

Once an archaeological permit has been requested in Nunavut the Inuit Heritage Trust has the responsibility of contacting the community that is located closest to the proposed dig site. The party requesting the permit is actually encouraged to contact the community directly and establish a relationship with the community in which to draw local knowledge and field assistants (Stenton, 2003:9).

It is required in the legislation that a report must be filed on the condition of every archaeological site an archaeologist visits, even if only a brief walk through (Stenton, 2003). These reports have the potential to be used in the creation and implementation of triage criteria if the time ever arrives that a policy is put in place to take a proactive role in preserving or salvaging sites that face destruction from a non-human development source. As of yet there is no heritage legislation in Nunavut that specifically addresses threats to archaeological sites solely from "environmental" sources such as the effects of climate change, only threats from development. However, it is argued that if legislation exists for protecting archaeological sites from human development, it should also exist for protection from other human correlated threats, such as climate change.

5.2.4 Difficulties of Developing Broad Canadian Initiatives

There are many challenges presented by a warming climate to heritage management in Canada, as the geographic landscape is vast, encompassing land spanning three oceans, multiple time zones, a wide array of climates, 14 different heritage legislations, and a multitude of cultures. There are many voices that aim to take precedence in regards to policy making of heritage management. There are First Nations and Inuit communities. There are also environmental protection groups, land owners, scholars, developers, politicians and others who feel they have a stake in any procedure developed (Levy, 2007:174). It can be a difficult path to attempt to find a compromise acceptable to all parties. Perhaps it is time that preservation of archaeological sites is placed first in order of precedence and all others viewed through this lens.

5.2.5 Aboriginal Involvement

The aboriginal voice is gaining in volume regarding a vast array of issues, most especially the loss of physical cultural heritage. Aboriginal concerns over the future of local archaeological sites are variable, but increasing across the globe and this concern must be met by all responsible parties. In some areas there is considerable involvement of aboriginal groups in cultural heritage management activities; this can be governmentally mandated or voluntary. The participation of First Nations groups can contribute local skills and knowledge to heritage sites as well as providing a cultural and economic outlet in return. The involvement of local aboriginal groups can have enormous cost saving benefits in regard to the management of heritage sites. The monitoring of long term damage done through environmental degradation and weather events is a top concern with heritage management professionals, and utilizing groups that have a cultural link and geographical connection to a site is an extremely efficient method of doing this. At a minimum, a cursory documentation of as many sites as possible is a necessary step in the development of policies and criteria of importance for policy makers, and this can also be done much more rapidly and efficiently by involving aboriginal communities. This involvement on behalf of all participants demonstrates a level of respect and acknowledgement to local communities that is crucial in order to move heritage management through the 21st century and the complex problems of managing our built heritage in the midst of a changing climate (Gregory, 2009).

5.3 Large-scale multi-disciplinary projects on physical heritage and climate change

After discussing a specific problem in a specific context (Sannirut), it is important to realize nothing exists in a wholly contained situation. Below are discussed some large scale solutions and approaches that can be used to help create long term solutions for sites such as Sannirut. At minimum their structures and approaches can be emulated in the creation of long-term heritage management plans for Canada and Nunavut.

Climate change effects vary greatly from locality to locality but they nevertheless have an effect upon almost every region of the globe. Different environmental conditions are involved, with a vast number of archaeological sites, each requiring specialized reactions and interactions on the part of heritage management staff. In recent years, more and more heritage projects are becoming international projects requiring cooperation from many different sciences. It is not simply a case of simple archaeological digs taking place in individual countries, but joint efforts designed to tackle the problems facing heritage everywhere. Some of these projects are described below, as well as initiatives taken that can be used to develop Canadian models and initiatives.

5.3.1 Heritage conventions and danger lists

Global initiatives and protocols concerning protection and preservation efforts of cultural heritage resources are feasible as demonstrated by the 1954 *Hague Convention on the Protection of Cultural Property in the Event of Armed Conflict,* along with the First (1954) and Second (2004) Protocols that clarified and amended the agreement. This document was the first of its kind to deal exclusively with cultural resources such as museums, monuments and archaeological sites.

There are 121 nation states, including Canada, involved in either one or all three parts to the convention and there are set guidelines as to responsibilities and actions, even criminal charges taken in times of conflict (Gerstenblith, 2009:78). This convention demonstrates the global will to take action to preserve heritage resources that could potentially face severe threats from conflict, and while threats from a warming climate differ significantly from looting or bombing, the results are the same: the decimation of a nation's cultural resources. Recognition of the looming issues of global warming toward archaeological resources should result in some form of political action, and perhaps a joint initiative, guidelines or even examples set by forward thinking nations could be the drive to create a proactive agreement on this universal issue.

The World Heritage Committee currently has no existing World Heritage Site placed on the official Danger List because of climate change. The World Heritage Committee is, however, making recommendations for participating nations to begin planning heritage management strategies with foresight to the effects global warming will have (Mitchell, 2008:1099). The World Heritage Convention was put forth in 1972 and as of 2007, 184 nations have either ratified or accepted (Canada has accepted), the agreement. Parties with membership have a number of preservation commitments towards sites in their own countries as well as internationally. To date the Committee has received six petitions to relocate existing World Heritage sites to the List of World Heritage Sites in Danger based on threats posed by global warming. In all of the petitions it has been groups or individuals pleading the case and not political parties. None of the petitions has yet been accepted (Shearing, 2007:5-6).

5.3.2 Engineering Historic Futures

University College London is conducting a case study entitled, *Engineering Historic Futures* (http://www.ucl.ac.uk/sustainableheritage/historic_futures.htm). The main initiatives of this project are to develop solutions to mitigate water damage to the structures, fabrics and contents of historic buildings. This is a climate change initiative as the instances of flooding and humidity are increasing and are predicted to continue to do so. Amongst their tasks are the creation of solutions that will remove moisture and mold from historic buildings without harming or altering in any way the textiles present, such as wallpaper, or damaging the structure itself. For Great Britain moisture and water damage are the primary concerns for heritage management and global warming scenarios. The project involves five funding partners: English Heritage, Historic Scotland, The National Trust, Ecclesiastical Insurance Group, and Munters Dehumidification Ltd. There are also four research partners including: The Centre for Sustainable Heritage University College London, The Bartlett School of Graduate Studies University College London, The School of Engineering, Science and Design Glasgow Caledonian University, and The Department of Mechanical Engineering Strathclyde University. This project is being conducted with participants located solely in Great Britain, but amongst a great number of professionals and disciplines. The multidisciplinary nature of the project broadens the funding base from which to draw upon with multiple academic departments and private companies.

Other projects, such as the Noah's Ark Project, focus on the broader spectrum of preparing the world's heritage for the next century.

5.3.3 Noah's Ark Project

The Noah's Ark Project (http://noahsark.isac.cnr.it/), is a multi-disciplinary undertaking involving several European partners. The main initiatives of the project are to disseminate information, to develop mitigation strategies, to act as policy advisors, and to create Climate Risk Maps and a Vulnerability Atlas in order to visualize future heritage scenarios. The information is passed on through news releases, an internet website, and bulletins, and by individual requests by interested parties. The project analyzes the effects of things such as freeze-thaw cycles, wind and storm events and radiation on built heritage, with the ultimate goal of using this information to develop mitigation plans. The maps are meant to highlight which geographical areas are at most risk and just how the predicted conditions will affect those areas. The project began in 2004 with a budget of €1,200,000 provided by the European Commission (Young, 2004:15) and has since released several press reports in six different countries as well as various reports and maps. The Noah's Ark Project is a massive undertaking, and a clear demonstration that climate change is expected to affect archaeological heritage worldwide.

5.3.4 Centre for Sustainable Heritage

In England the Centre for Sustainable Heritage at University College London created a report for English Heritage in which it narrowed the effects of Climate change on the historic environment in England to five key issues to present to policy makers. This approach is possible to emulate in Canada. The first step in the process was to create a list of every possible concern relating to climate change and the preservation of heritage sites. Next a detailed questionnaire of these concerns was designed and circulated to a broad range of heritage professionals. The results of the questionnaire, along with input from a diverse range of site visits to interview site personnel and regional workshops with heritage professionals, were utilized to refine global warming concerns to five key issues regarding heritage management. The results of the questionnaires and site visits were further refined through policy-makers' workshops where prioritization criteria were developed. The accumulated research was then summarized in a report delivered to English Heritage (Cassar, 2005:21).

5.3.5 Possible emergency response and communication structure

Australia is in the forefront of developing emergency contingency plans that are useful for modeling by other nations. For example their State Emergency Services is a volunteer organization receiving funding through donations and government branches. One of the functions of this service is to protect property before more damage can be done from environmental disasters such as flooding or extreme storms. Detailed information on this program can be found on their website http://www.emergency.qld.gov.au/ses/ (Cassar, 2005:2). A similar network of volunteers funded through the Canadian and Territorial/Provincial governments could be trained to react in emergency situations such as flooding or major wind events, to mitigate damage to archaeological sites. This could possibly involve lists and maps of local heritage, an early warning system, disaster training such as sandbagging and various other activities. A program such as this would be dependent upon region and accessibility. This approach would only be effective in the Arctic if the archaeological sites in question were in the immediate vicinity of communities. The environment and terrain of the north provide too many challenges to enable wide scale emergency action plans for more than a very limited number of sites.

The present Nunavut legislation discussed above indicates that the background is there to implement and then support future preservation efforts pertaining to climate change. The various components of current legislation, such as requiring as much Inuit involvement as possible, will be crucial for monitoring and site maintenance. The legislative structure that already requires preservation of archaeological heritage from human induced threats, climate change needs to be acknowledged as one of these threats. The major international projects such as the Noah's Ark Project, demonstrate that some non-Canadian governments and organizations are already reacting to predicted threats and are creating heritage management plans in preparation; this indicates that there are precedents and models that Canada can emulate.

Chapter 6
Conclusions and Recommendations

6.1.1 Climate and Archaeology

For those who accept the phenomenon of global warming, the changes predicted within this century are ones to be prepared for and in some cases to be alarmed at. The average temperature will rise between 1.1˚Celsius and 6.4 ˚Celsius with a corresponding rise of approximately one metre in sea level, and an increase in the ferocity and quantity of extreme weather events (IPCC, 2007). The scenarios change depending upon geographic location, but peoples in every part of the world will experience changing conditions that will affect their ability to manage their archaeological heritage. Warm and arid locations can expect to see an increase in those pre-existing conditions along with rises in wildfires and chemical changes in the soil. Coastal regions will be inundated by the rising sea levels, high atmospheric humidity, saturated soil beds, and extreme wave action. These changes will affect the survival of both built and buried archaeology; many regions are already experiencing the loss of many archaeological sites due to these processes and this trend can only be expected to increase. Northern regions, however, are the areas thought likely to be the most vulnerable to a warming climate.

The Arctic ecosystems maintain a vulnerable balance that is easily upset. The feedback cycles of the cryosphere involving permafrost, permafrost gases, and the loss of ice to reflect radiation back into the atmosphere, cause the effects of global warming to be amplified. For that reason the Arctic is actually a prime location to monitor the effects of global warming upon archaeological heritage. Archaeological sites here are particularly vulnerable to the thawing of the protective permafrost surrounding them. When the permafrost thaws it can cause heaving of the soil which destroys the stratigraphy of a site and can damage artifacts. Sensitive organic materials also begin to breakdown when thawed or exposed.

Erosion caused by rising water levels and unstable thawed soils is another source of site degradation in the Arctic. The Arctic is already losing sites rapidly and with the effects of climate change predicted to continue and escalate, the losses will continue.

Heritage professionals across the globe are beginning to be confronted with the challenges of changing climate conditions and are beginning to respond in various ways.

6.1.2 Case study summary

There are large multi-disciplinary projects being conducted that are not site specific projects, but are attempting to deal with the symptoms of climate change such as the UK's *Engineering Historic Futures* project. This project brings together any discipline that may contribute to mitigating water damage to historic buildings. There are projects that go even larger, becoming multi-national, such as the *Noah's Ark* project that was created as a vehicle to disseminate knowledge of climate change effects to heritage sectors, to create vulnerability maps and to create heritage degradation scenarios. A project such as this is visibly lacking in North America and I would propose that such predictive models and vulnerability maps would be an invaluable tool in the Canadian Arctic to establish a set of criteria for the implementation of heritage policies dealing with global warming.

There are many site specific case studies from every region of the world which demonstrate that heritage legislation regarding action upon climate change is an immediate need and not a long term goal. Australia and Greece are both experiencing more frequent and catastrophic heat waves which are drying out the vegetation and weakening the soil chemistry making soils lighter and drier. This combination means that wildfires are becoming more common and are burning uncontrollably.

In 2007 Greece almost lost all the monuments and sites on Mount Olympus but for the massive numbers of firefighters, volunteers, and the highly technical watering system that had been installed shortly beforehand. Greece is a leader in the creation of a 20 year contingency legislation plan dealing with global warming. Australia's approach is less high tech, relying on a highly trained emergency response program and providing fire prevention equipment and visitor training near their historic homestead and bush hut sites. Other arid or semi-arid regions are experiencing invasive desertification. This is the case in Mongolia where some regions are attempting to combat the sand with green barriers. Green barriers are vegetation planting, such as poplar trees to hold back shifting dunes.

Coastal erosion and flooding are, and will continue to be, two of the more prevailing environmental issues affecting archaeological sites. Britain protects such land-marks as the Tower of London with physical man-made barriers called the Thames Barriers, to prevent floodwaters from entering London. Physical barriers, however, do have the drawback of only diverting the water which does eventually have to go somewhere, and therefore other archaeological sites may be compromised elsewhere. Other places in the world such as Herschel Island, Canada, are taking the approach of physically moving some of their historic buildings inland or away from erosion-prone areas.

The thawing of permafrost is an issue that most far northern areas are experiencing right now. Fort Conger in Nunavut is using 3D technology to document the historic site in preparation for its loss. Researchers working on the Altai tombs of Siberia are also conducting mass documentation as well as attempting to find strategies to stabilize the permafrost for at least some of the tombs. While in Canada's Yukon Territory, Ice Patch researchers and local First Nations groups are working collaboratively to salvage as much information and artifacts as possible as they are released from the ice and permafrost.

6.1.3 Sannirut

Just as in the above case studies, the Sannirut site on Bylot Island, Nunavut Territory has important cultural value and is facing immediate threat from a warming climate. Sannirut has a history of almost continuous occupation dating back 4500 years from the Pre-Dorset period to modern Inuit use today. The permafrost and soil chemistry of the site is remarkably kind to fragile and rare organic artifacts such as the unique life-sized wooden Dorset masks found there. The site itself encompasses a small peninsula of around 400 metres in length and is covered by a thick layer (almost one metre) of permafrost infused turf. It was first noticed in the 1970's by Guy Mary-Rousselière that large portions of the peat were slumping away from the site down the embankment and being swept away by the sea. Since that time the slumping has only escalated. There is no specific legislation in Nunavut that pertains to taking action to protect a site from the consequences of climate change. However, the permit system and land claims agreement all contain necessary components to conduct this research, such as involvement with local communities and the documentation of the condition of all sites a researcher discovers. There are several possibilities that may work to preserve the permafrost of Sannirut, with thermosyphons and some form of thermal blanketing such as polyurethane in combination with any necessary salvage excavation being the most likely.

6.2 Conclusions

Archaeological sites are going to be affected to a greater and greater extent in the future by climate change and numerous ones will undoubtedly be destroyed, but it should be possible to preserve many. Degradation of sites is simply taken for granted–there is no site in pristine condition untouched by time; artifacts and features have developed and faded since time immemorial. There are some parties that may argue that all archaeological sites/artifacts will follow the common western human eulogy of 'dust to dust', so therefore why place such importance on the ephemeral as tangible heritage?

While this may not be a common sentiment among heritage professionals, most do recognize that it simply is not feasible to preserve or salvage every single archaeological site that is threatened by development or environmental degradation. There is never enough time, funding or manpower especially for government branches, to divert significant resources away from development driven work toward 'natural' situations. Decisions will have to and are being made on which sites are beyond saving or simply not feasible to save such as Blakeny Chapel in England.

Sannirut is going to be affected by global warming. If the permafrost continues to thaw, and the rate of slumping at the site continues, there will not be a site to preserve. Action must be taken with some immediacy if action is to be taken at all. Archaeological sites are going to have to be given criteria on the priority of their situations as not all sites can be preserved. By this I mean that a relative value will need to be placed on all discovered sites based on a set of criteria to establish the cultural and research importance of each site. The sites that rank the highest on these scales may be the ones which receive the most immediate attention. These criteria have not been established and I have not created them in this paper, however, I do believe historic value and links to local communities, the immediacy of the threat, the research potential of the site, and the current condition (if it's salvageable) of the site will all be fundamental if preservation criteria are ever established. Sannirut satisfies all of these suggested criteria. The tools to stabilize Sannirut are available, including thermosyphons, thermal blankets and long term monitoring solutions. Collaboration with the local community of Pond Inlet will be critical in monitoring and maintenance of the site and there is an excellent opportunity for training to be provided to members of the community.

6.3 Recommendations

Regardless of personal or political stances on the issues of climate change adopting policy changes and adaptable preservation models to site management will have a positive impact upon archaeological sites. Acting now with consideration to the eventual outcomes of a warming climate will lead to a greater longevity for archaeological heritage which will benefit from future technologies. New non-invasive technologies, such as ground penetrating radar, are being developed all the time which allow for research on an archaeological site without the resulting destruction of actual excavation. Leaving at least a portion of archaeological sites unexcavated will also allow for new excavation techniques and different research agendas. There will also be a corresponding decrease in the number of non-essential salvage excavations at least in regards to environmental degradation.

By adopting and modifying successful initiatives developed by other nations, Canada and Nunavut will be better prepared to deal with the challenges of the 21st century. Initiative's such as the Noah's Ark project with its vulnerability maps and public dissemination directives, and Australia's emergency response plan are examples of efficient strategies in communication involving a wide geographic area.

6.3.1 Funding Recommendations

The main financial problem of climatic threats on archaeology is that there is not an individual or party standing by the bulldozer that can be held legally accountable to deal with the monetary burden of preserving or salvaging the site. There is extensive legislation involving archaeological heritage threatened by developers and their bulldozers, and this involves financial responsibility towards recovering all possible information from the site.

The lack of a party directly responsible for global warming will leave government bodies holding the hat for the financial burden, and the political process is slow to turn. Global warming policy changes will, out of necessity, have to involve long term planning while political terms are short. This can make things difficult especially if long range plans involve a high initial financial output where any potential gains will not be seen in any one political term. The financial aspect of preserving exposed artifacts and human remains *in situ* and out (i.e./in museums), is a significant consideration in these times where heritage monies are shrinking. Sources of funding will have to be one of the most urgent and basic tasks of heritage management professionals. I'm sure there are several ways to approach this, but the suggestions I have are described below.

The most obvious source of funding is to make use of what is already in place. This involves sources of funding and support from organizations such as the Polar Continental Shelf Program, Social Science Humanities Research grants, Canadian Heritage and various other agencies. Competition for these funds can be fierce. If funding organizations make a preference towards funding those projects that involve threatened sites, it could influence enough research to make a significant contribution to the research of sites that otherwise would be lost.

When it comes to electronic items such as televisions or computers, consumers are automatically charged an environmental disposal fee to pre-emptively prepare for when the consumer is done with it. A similar heritage preservation fee or tax could be implemented in slow increments for certain consumer items or possibly developments such as purchasing new homes. It is difficult to have a socially conscious reason for opposing such a fee especially if it were kept quite minimal.

A more likely method of finding the resources to handle the volume of sites in danger, at least for Nunavut, would be to restrict archaeological permits to researchers who could demonstrate that the site(s) they wished to work on were in immediate environmental danger. In this way it would help to ensure that sites that are environmentally secure are preserved *in situ* while more sites that would otherwise be lost are at least minimally researched and the artifacts and information possibly salvaged.

6.3.2 Sannirut Recommendations

To maximize the success of any efforts on the preservation of Sannirut, a decision must be made on whether to take an action or not. In time if no action is taken, Sannirut like the nearby Saatut site and many others will continue to erode and slump to be washed away by the sea. For the reasons of Sannirut's remarkable preservation of rare wooden objects, such as the life-sized wooden masks found decades ago, and the continuous cultural history of the site, this would be a terrible cultural loss. Another argument for the decision to act is simply because we can. This site has the potential to be preserved. There are many methods that might allow us to stabilize the permafrost and there is no human development threat looming on the horizon, and therefore the site can be successfully preserved for the most part *in situ* if action is taken. The environmental threats and development threats are not to the degree that any action would be pointless.

If it is decided that the time, people and funds are available to preserve Sannirut, then a period of experimentation over a couple of field seasons would enable the most efficient and effective methods to come to light. The first year will consist of data gathering. Samples of the permafrost must be collected to learn ice consistency, soil and surface temperatures recorded for baselines, and exact measures of the site and extent of the slumping taken. Any salvage excavation deemed necessary would be undertaken for areas that would not last until the following year. Depending on time constraints, either that year or the following would see a trial of the different methods available. This would involve installing several thermosyphons, a ground and surface monitor, perhaps a small area of fencing, and one or more thermal blanketing methods.

The different thermal blanketing methods would include polyurethane spray, gravel, and some form of shading structure out of wood or plastic. The following field season would see more extensive salvage excavations of the areas that have already thawed and slumped with those areas then backfilled with the screened material. The methods that were the most effective in the testing stage would then be utilized throughout the site. I believe it will end up being a compilation of salvage excavations, thermosyphons and some blanketing that will preserve Sannirut for several more decades.

An important part of the success of any strategy utilized will be the continued participation of the local community (in this case Pond Inlet) in the years following. The local community would need to be trained in how to monitor any equipment used and perform basic maintenance. Acceptance on the part of Inuit would be necessary or at least very desirable in order to even begin the project with current Nunavut legislation, and would be vital to its continued success in terms of monitoring.

With successful strategies in place on how to deal with environmental difficulties on Arctic archaeology it will make it easier for policy makers to demonstrate that creating heritage legislation for global warming is a plausible task not just a necessary one. It is legislation that provides a common link between archaeology and all stakeholders at least in the geographic areas divided by province and territory. Legislation can provide guidelines and a baseline for very disparate interests and allow a common motivation to move archaeology in a sustainable direction.

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